TÜV RHEINLAND
ENERGIE UND UMWELT GMBH

Deutsche Akkreditierungsstelle
D-PL-11120-02-00

Report on the performance testing of the Serinus 10 ambient air quality monitoring system manufactured by Ecotech Pty Ltd measuring ozone

TÜV Report: 936/21221977/C_EN
Cologne, 08 October 2013

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is accredited for the following work areas:

- Determination of air quality and emissions of air pollution and odour substances;
- Inspection of correct installation, function and calibration of continuously operating emission measuring instruments, including data evaluation and remote emission monitoring systems;
- Combustion chamber measurements;
- Performance testing of measuring systems for continuous monitoring of emissions and ambient air, and of electronic data evaluation and remote emission monitoring systems;
- Determination of stack height and air quality projections for hazardous and odour substances;
- Determination of noise and vibration emissions and pollution, determination of sound power levels and execution of sound measurements at wind energy plants

according to EN ISO/IEC 17025.

The accreditation is valid up to 22-01-2018. DAkkS-register number: D-PL-11120-02-00.

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DAkkS Deutsche Akkreditierungsstelle D-PL-11120-02-00

Report on the performance testing of the Serinus 10 ambient air quality monitoring system manufactured by Ecotech Pty Ltd measuring ozone

Instrument tested: Serinus 10

Manufacturer: Ecotech Pty Ltd
1492 Ferntree Gully Road
Knoxfield VIC Australia 3180
Australia

Test period: April 2013 to October 2013

Date of report: 08 October 2013

Report number: 936/21221977/C_EN

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Scope of report:

Report:		121	pages
Manual	page	121	et seq.
Manual	of	138	pages
Total		259	pages

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Contents

List of tables

List of figures

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1. Summary and certification proposal

1.1 Summary

Ecotech Pty Ltd has commissioned TÜV Rheinland und Umwelt GmbH to carry out performance testing of the Serinus 10 measuring system for ozone.

Testing was performed in compliance with the following standards and guidelines:

- VDI Guideline 4202 Sheet 1: Performance criteria for performance tests of automated ambient air measuring systems; Point-related measurement methods for gaseous and particulate air pollutants, September 2010
- VDI Guideline 4203 Sheet 3: Testing of automated measuring systems; Test procedures for point related ambient air measuring systems for gaseous and particulate air pollutants, September 2010
- DIN EN 14625: Ambient air – Standard method for the measurement of the concentration of ozone by ultraviolet photometry, December 2012

The measuring system Serinus 10 uses the method of ultraviolet photometry, which serves as a reference method in the EU, to measure ozone. Tests were performed in the laboratory as well as during a three month field test in Cologne. The measured ranges were as follows:

Table 1: Measured ranges during testing

Measured component	Measured range in [µg/m³] [1)]	Measured range in [ppb] or [nmol/mol]
Ozone	0 – 500	0 - 250

[1)] The data refer to 20°C and 101.3 kPa

Minimum requirements were met during performance testing.

TÜV Rheinland Energie und Umwelt GmbH therefore suggests its type approval for continuous measurement of ozone concentrations in ambient air.

1.2 Certification proposal

Due to the positive results achieved, the following recommendation is put forward for the notification of the AMS as a type-approved measuring system:

AMS designation:

Serinus 10 for ozone

Manufacturer:

Ecotech Pty Ltd, Knoxfield, Australia

Field of application:

Continuous measurement of ozone concentrations in ambient air from stationary sources.

Measured ranges during performance testing:

Component	Certification range	Unit
Ozone	0 - 500	µg/m³

Software version:

Firmware: 2.09.0005

Restrictions:

None

Notes:

1. The measuring system has to be operated in a lockable measuring cabinet or container.
2. The test report on the performance test is available online at www.qal1.de.

Test report:

TÜV Rheinland Energie und Umwelt GmbH, Cologne

Report no.: 936/21221977/C_EN dated 08 October 2013

1.3 Summary of test results

Performance criterion		Minimum requirement	Test result	Compliance	Page
4	**Requirements on the instrument design**				
4.1	**General requirements**				
4.1.1	Measured value display	Shall be available.	The measuring system is fitted with a measured value display.	yes	35
4.1.2	Easy maintenance	Necessary maintenance of the measuring system should be possible without larger effort, if possible from outside.	Maintenance can be carried out with usual tools in a reasonable time and from the outside.	yes	36
4.1.3	Functional check	If the operation or the functional check require particular instruments, they shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.	The tested instrument does not have an internal device for functional checks.	not applicable	37
4.1.4	Set-up times and warm-up times	The set-up times and warm-up times shall be specified in the instruction manuals.	Set-up times and warm-up times were determined.	yes	38
4.1.5	Instrument design	The instruction manual shall include specifications of the manufacturer regarding the design of the system.	The specifications of the manual with regard to instrument design are complete and correct.	yes	39
4.1.6	Unintended adjustment	It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation.	The measuring system itself is not protected against the unintended or unauthorised adjustment of instrument parameters. It has to be operated in a lockable measuring container.	no	40
4.1.7	Data output	The output signals shall be provided digitally and/or as analogue signals.	Measured signals are provided in analogue (0-20 mA, 2-20 mA, 4-20 mA or 0-5 V) and digital form (via TCP/IP, RS232, USB; Bluetooth).	yes	41

Performance criterion	Minimum requirement	Test result	Com-pliance	Page
5. Performance characteristics				
5.1 General	The manufacturer's specifications in the instruction manual shall be by no means better than the results of the performance tests.	No discrepancies between the instrument design and the instruction manuals were observed.	yes	42
5.2 General requirements				
5.2.1 Certification range	Shall meet the requirements of Table 1 of VDI Guideline 4202 Part 1.	The measuring system can be assessed in the range of the relevant limit values.	yes	43
5.2.2 Measuring range	The upper limit of measurement of the measuring systems shall be greater or equal to the upper limit of the certification range.	By default the measuring range is set to 0 – 500 µg/m³ for ozone. Other measuring ranges of max. 0 – 20 ppm are possible. The upper limit of the measuring range is larger than the respective upper limit of the certification range.	yes	44
5.2.3 Negative output signals	May not be suppressed (life zero).	The measuring system also displays negative measured values.	yes	45
5.2.4 Failure in the mains voltage	In case of malfunction of the measuring system or failure in the mains voltage, uncontrolled emission of operation and calibration gas shall be avoided. The instrument parameters shall be secured by buffering against loss. When mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement.	When mains voltage returns the measuring system goes back to a failure-free operational status and automatically resumes measuring.	yes	46
5.2.5 Operating states	The measuring system shall allow the control of important operating states by telemetrically transmitted status signals.	By means of various connectivity options and the "Serinus Downloader" software the measuring system can be monitored and controlled from an external PC.	yes	47
5.2.6 Switch-over	Switch-over between measurement and functional check and/or calibration shall be possible telemetrically by computer control or manual intervention.	In general, all necessary tasks related to functional checks may be performed directly on-site or monitored telemetrically using the remote control functions.	yes	48
5.2.7 Maintenance interval	Preferably 3 months but at least 2 weeks.	As determined by the necessary maintenance tasks the maintenance interval is 4 weeks.	yes	49
5.2.8 Availability	At least 95 %.	Availability for both systems was 100 % incl. maintenance times during testing.	yes	50
5.2.9 Instrument software	Shall be displayed during switch-on of the measuring system. The test institute shall be informed on changes in the instrument software, which in-	The instrument software version is indicated in the display. Changes to the software will be communicated to the test institute.	yes	51

	fluence the performance of the measuring system.			

Performance criterion	Minimum requirement	Test result	Compliance	Page
5.3 Requirements on measuring systems for gaseous air pollutants				
5.3.1 General	Minimum requirements as per VDI Guideline 4202 Sheet 1.	The tests were performed on the basis of the minimum requirements as stipulated in VDI 4202, Sheet 1 (September 2010) as well as Standard DIN EN 14625 (2012).	yes	52
5.3.2 Repeatability standard deviation at zero point	The repeatability standard deviation at zero point shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010) in the certification range specified in Table 1 of the same guideline.	Please refer to section 7.1 8.4.5 Repeatability standard deviation.	yes	53
5.3.3 Repeatability standard deviation at reference point	The repeatability standard deviation at reference point shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010) in the certification range according to Table 1 of the same guideline.	Please refer to section 7.1 8.4.5 Repeatability standard deviation.	yes	54
5.3.4 Linearity (lack of fit)	The analytical function describing the relationship between the output signal and the value of the air quality characteristic shall be linear.	Please refer to section 7.1 8.4.6 Lack of fit of linearity of the calibration function.	yes	55
5.3.5 Sensitivity coefficient of sample gas pressure	The sensitivity coefficient of sample gas pressure at reference point shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010).	Please refer to section 7.1 8.4.7 Sensitivity coefficient to sample gas pressure.	yes	56
5.3.6 Sensitivity coefficient of sample gas temperature	The sensitivity coefficient of sample gas temperature at reference point shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 (September 2010).	Please refer to section 7.1 8.4.8 Sensitivity coefficient to sample gas temperature.	yes	57
5.3.7 Sensitivity coefficient of surrounding temperature	The sensitivity coefficient of surrounding temperature at zero and reference point shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010).	Please refer to section 7.1 8.4.9 Sensitivity coefficient to the surrounding temperature.	yes	58

Performance criterion	Minimum requirement	Test result	Compliance	Page
5.3.8 Sensitivity coefficient of supply voltage	The sensitivity coefficient of supply voltage shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010).	Please refer to section 7.1 8.4.10 Sensitivity coefficient to electrical voltage.	yes	59
5.3.9 Cross-sensitivity	The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010) at zero and reference point.	Please refer to section 7.1 8.4.11 Interferents.	yes	60
5.3.10 Averaging effect	For gaseous components the measuring system shall allow the formation of hourly averages. The averaging effect shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010).	Please refer to section 7.1 8.4.12 Averaging test	yes	61
5.3.11 Standard deviation from paired measurements	The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test. It shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010).	Please see section 7.1 8.5.5 Reproducibility standard deviation for ozone under field conditions.	yes	62
5.3.12 Long-term drift	The long-term drift at zero point and reference point shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010) in the field test.	Please refer to section 7.1 8.5.4 Long-term drift.	yes	63
5.3.13 Short-term drift	The short-term drift at zero point and reference point shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010) within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test.	Please refer to section 7.1 8.4.4 Short-term drift.	yes	64

Performance criterion	Minimum requirement	Test result	Com-pliance	Page
5.3.14 Response time	The response time (rise) of the measuring system shall not exceed 180 s. The response time (fall) of the measuring system shall not exceed 180 s. The difference between the response time (rise) and response time (fall) of the measuring system shall not exceed 10 % of response time (rise) or 10 s, whatever value is larger.	Please refer to section 7.1 8.4.3 Response time.	yes	65
5.3.15 Difference between sample and calibration port	The difference between the measured values obtained by feeding gas at the sample and calibration port shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010).	Please refer to section 7.1 8.4.13 Difference sample/calibration port.	yes	66
5.3.16 Converter efficiency	In case of measuring systems with a converter, the converter efficiency shall be at least 98 %.	This test item does not apply as the measuring system does not use a converter.	Not applicable	67
5.3.17 Increase of NO2 concentrations due to residence in the measuring system	In case of NO_x measuring systems the increase of NO_2 concentration due to residence in the measuring system shall not exceed the requirements listed in Table 2 of VDI Guideline 4202 Sheet 1 (September 2010).	Not applicable as the measuring system does not measure NOX.	not applicable	68
5.3.18 Overall uncertainty	The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives specified in the applicable EU Directives on air quality as listed in Annex A, Table A 1 of VDI Guideline 4202 Sheet 1 (September 2010).	The determination of uncertainty was performed in accordance with DIN EN 14625(2012) and is detailed in section 7.1 8.6 Total uncertainty in accordance with Annex E of DIN EN 14625 (2012).	yes	69

Performance criterion	Minimum requirement	Test result	Compliance	Page
8.4 Requirements of Standard DIN EN 14625				
8.4.3 Response time	Neither the response time (rise) nor the response time (fall) shall exceed 180 s. The difference between rise and fall response time shall not exceed 10 s.	The maximum permissible response time of 180 s is exceeded at no time. The maximum response time determined is 53 s for system 1 and 51 s for system 2.	yes	70
8.4.4 Short-term drift	The short-term drift at zero shall not exceed 2.0 nmol/mol/12 h (i.e. 4.0 µg/m³/12h). The short-term drift at span level shall not exceed 6.0 nmol/mol/12 h (i.e. 12.0 µg/m³/12 h).	The short term drift at zero is 0.49 nmol/mol for system 1 and -1.04 nmol/mol for system 2. The short-term drift at span point is 1.89 nmol/mol for system 1 and 1.91 nmol/mol for system 2.	yes	74
8.4.5 Repeatability standard deviation	The repeatability standard deviation shall neither exceed 1.0 nmol/mol (i.e. 2.0 µg/m³) at zero nor shall it exceed 3.0 nmol/mol (i.e. 6.0 µg/m³) of the test gas concentration at span point.	The repeatability standard deviation at zero point is 0.32 nmol/mol for system 1 and 0.60 nmol/mol for system 2. The repeatability standard deviation at reference point is 0.16 nmol/mol for system 1 and 0.40 nmol/mol for system 2.	yes	78
8.4.6 Lack of fit of linearity of the calibration function	The lack of fit of linearity of the calibration function shall not exceed 5.0 nmol/mol (i.e. 10.0 µg/m³) at zero point and 4 % of the measured value at concentrations above zero.	For system 1, the deviation from the regression line is 1.38 nmol/mol at zero point and max. 1.25 % of the target value for concentrations greater than zero. For system 2, the deviation from the regression line is 1.16 nmol/mol at zero and max. 1.50 % of the target value for concentrations greater than zero.	yes	81
8.4.7 Sensitivity coefficient to sample gas pressure	The sensitivity coefficient to sample gas pressure shall not exceed 2.0 nmol/mol/kPa (i.e. 4.0 µg/m³/kPa).	For system 1, the sensitivity coefficient to sample gas pressure is 0.06 nmol/mol/kPa. For system 2, the sensitivity coefficient to sample gas pressure is 0.04 nmol/mol/kPa.	yes	86

Performance criterion	Minimum requirement	Test result	Compliance	Page
8.4.8 Sensitivity coefficient to sample gas temperature	The sensitivity coefficient to sample gas temperature shall not exceed 1.0 nmol/mol/K (i.e. 2.0 µg/m³/K).	For system 1, the sensitivity coefficient to sample gas temperature is 0.13 nmol/mol/K. For system 2, the sensitivity coefficient to sample gas temperature is 0.14 nmol/mol/K.	yes	88
8.4.9 Sensitivity coefficient to the surrounding temperature	The sensitivity coefficient to the surrounding temperature shall not exceed 1.0 nmol/mol/K (i.e. 2.0 µg/m³/K).	The sensitivity coefficient bst to the surrounding temperature does not exceed the performance criteria of max. 1.0 nmol/mol/K. For both systems, the highest value bst is used for the purpose of evaluating uncertainty. For system 1 it is 1 0.421 nmol/mol/K and for system 2 it is 0.206 nmol/mol/K.	yes	90
8.4.10 Sensitivity coefficient to electrical voltage	The sensitivity coefficient to electrical voltage shall not exceed 0.30 nmol/mol/V (i.e. 0.60 µg/m³/V).	The sensitivity coefficient of electrical voltage bv does not exceed the performance criteria of max. 0.3 nmol/mol/V stipulated in Standard DIN EN 14625 at any point. For both systems, the highest value bv is used for the purpose of calculating uncertainty. For system 1 it is 0.01 nmol/mol/V and for system 2 it is 0.02 nmol/mol/V.	yes	93
8.4.11 Interferents	Interferents at zero concentration and at a concentration (at the level of the hourly limit value = 200 µg/m³ for NO_2). Maximum responses for the component H_2O is ≤ 10.0 nmol/mol (i.e. 20.0 µg/m³) and for toluene and m-Xylene ≤ 5.0 nmol/mol (i.e. 10.0 µg/m³) each.	Cross-sensitivity at zero point is 2.70 nmol/mol for system 1 and -001 nmol/mol for system 2 for the component H2O; 1.88 nmol/mol for system 1 and 2.02 nmol/mol for system 2 for toluene; 2.51 nmol/mol for system 1 and 2.68 nmol/mol for system 2 for m-Xylene. Cross-sensitivity at the limit value ct is -0.67 nmol/mol for system 1 and 0.72 nmol/mol for system 2 for H2O; 0.38 nmol/mol for system 1 and -0.82 nmol/mol for system 2 for toluene; 4.53 nmol/mol for system 1 and 3.86 nmol/mol for system 2 for m-Xylene.	yes	95
8.4.12 Averaging test	The influence of averaging shall not exceed 7 % of the instrument reading.	This is in complete compliance with the performance criteria stipulated DIN EN 14625.	yes	98

Performance criterion	**Minimum requirement**	**Test result**	**Compliance**	**Page**
8.4.13 Difference sample/calibration port	The difference in response of the analyser to feeding through the sample or calibration port shall not exceed 1 %.	This is in complete compliance with the performance criteria stipulated in Standard DIN EN 14625.	yes	101
8.4.14 Residence time in the analyser	The residence time inside the analyser shall not exceed 3.0 s.	The residence time inside the analyser 0.6 s.	yes	103
8.5.4 Long-term drift	The long-term drift at zero shall not exceed 5.0 nmol/mol (i.e. 10 µg/m³). The long-term drift at span level shall not exceed 5 % of the certification range (i.e. 12.5 nmol/mol in a measuring range of 0 to 250 nmol/mol).	The maximum long term drift at zero $D_{l,z}$ is 1.81 nmol/mol for system 1 and -1.47 nmol/mol for system 2. The maximum long term drift at span point $D_{l,s}$ is -2.25 % for system 1 and -2.44 % for system 2.	yes	104
8.5.6 Period of unattended operation	The maintenance interval shall be at least 2 weeks.	The maintenance interval is subject to the necessary maintenance tasks and is 4 weeks.	yes	111
8.5.5 Reproducibility standard deviation for ozone under field conditions	The reproducibility standard deviation under field conditions shall not exceed 5 % of the average value over a period of three months.	The reproducibility standard deviation for ozone was 1.95 % of the average over a period of 3 months in the field. Thus, the requirements of Standard DIN EN 14625 are met.	yes	108
8.5.7 Period of availability of the analyser	The availability of the measuring system shall be at least 90 %.	The availability is 100 %. This complies with the requirements of Standard DIN EN 14625.	yes	112

2. Task definition

2.1 Nature of the test

Ecotech Pty Ltd has commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out performance testing of the Serinus 10 measuring system. The test was a complete performance test.

2.2 Objective

The instrument is designed to measure the concentration of ozone in ambient air in the following concentration ranges:

Component	Certification range	Unit
Ozone	0 - 500	µg/m³

The Serinus 10 measuring system uses the method of ultraviolet photometry to measure ozone.

Performance testing was to be carried out in accordance with current standards taking into consideration the latest developments.

Testing was performed on the basis of the following standards and guidelines:

- VDI Guideline 4202 Sheet 1: Performance criteria for performance tests of automated ambient air measuring systems; Point-related measurement methods for gaseous and particulate air pollutants, September 2010
- VDI Guideline 4203 Sheet 3: Testing of automated measuring systems; Test procedures for point related ambient air measuring systems for gaseous and particulate air pollutants, September 2010
- DIN EN 14625: Ambient air – Standard method for the measurement of the concentration of ozone by ultraviolet photometry, December 2012

3. Description of the analyser tested

3.1 Measuring principle

The Serinus 10 measuring system is a continuous ozone monitor which uses the method of ultraviolet photometry. The instrument is designed for the continuous measurement of ozone concentrations in ambient air.

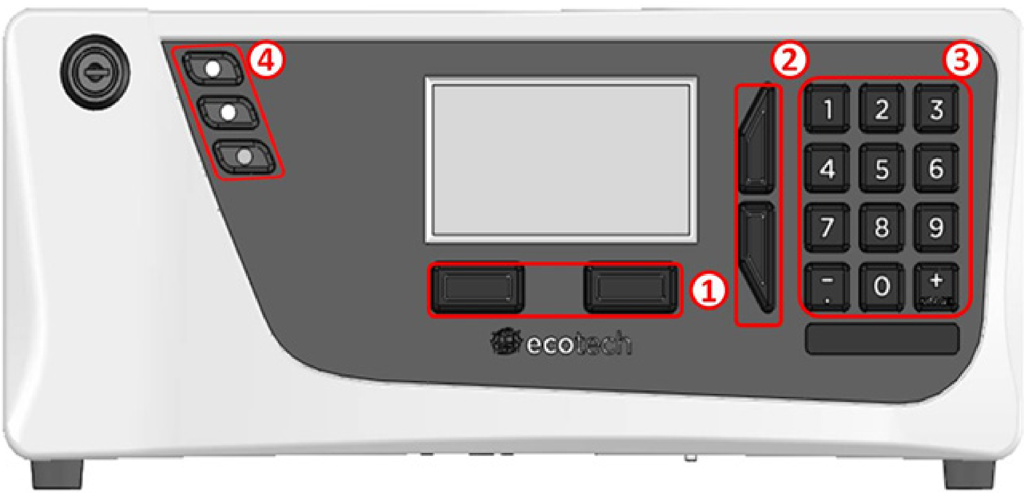


Figure 1: Representation of the Serinus 10 analyser

Ozone is measured on the basis of UV absorption analysis. The UV photometer determines the ozone concentration (O_3) in the sample gas at ambient pressure by detecting absorption of UV radiation in a glass absorption tube. The Serinus 10 works by the following principles and measurement methods:

- Ozone shows a strong absorption of UV light at a wavelength of 254 nm.
- Sample air is passed into the glass absorption tube (measurement cell).
- Within the measurement cell a single beam of UV radiation (from a mercury vapour lamp) passes through the sample and is absorbed by the O_3.
- The solar blind vacuum photodiode detects any UV that is not absorbed.
- The strength of the UV signal being detected is proportional to the amount of UV light being absorbed by O_3
- The Serinus 10 analyser uses the Beer-Lambert relationship (Beer-Lambert law) to calculate the ozone concentration.

The Beer-Lambert law (shown below) is used to calculate the concentration of ozone from the ratio of the two light intensities measured:

$$I/I0 = \exp(-acd)$$

where

- I is the light intensity measured with ozone in the gas sample
- I0 is the light intensity measured with no ozone in the gas sample
- a is the ozone absorption coefficient at 253.7 nm (1.44 x 10-5 m^2/mg)
- c is the mass concentration of ozone in mg/m^3
- d is the optical path length in m

• O_3 is not the only gas that absorbs UV (254 nm), SO_2 and aromatic compounds also absorb radiation at this wavelength. To eliminate interferences a second cycle is performed. Sample air is passed through an ozone scrubber, removing ozone but allowing all interfering gases through. Thus it is possible to accurately measure the effect of interfering gases. This effect is then removed from the sample measurement signal which ensures accurate measurement of ozone without the influence of interferents.

The microprocessor and electronics of the Serinus 10 control, measure, and correct for all the major external variables to ensure stable and reliable operation.

3.2 Analyser scope and set-up

The Serinus 10 Ozone Analyser uses non-dispersive ultraviolet (UV) absorption technology to measure ozone to a sensitivity of 0.5 ppb in the range of 0-20 ppm. The Serinus 10 measures O_3 with the following components and techniques:

- Mercury vapour lamp – to provide detector input.
  (254 nm UV light source)

- Photodiode detector – to capture the measurement response.
  Detects the ratio of transmitted light, thereby giving the concentration of ozone.

- Ozone scrubber – to establish the background response
  As ozone is not the only atmospheric gas that absorbs the particular wavelength of UV light.

- A microprocessor programmed with Serinus firmware monitors the detector response and many other parameters, so that the O_3 concentration is automatically corrected for gas temperature and pressure changes and referenced to 0 °C, 20 °C or 25 °C at 1 atmosphere. This allows the Serinus 10 to sample in the most common measurement range for O_3.

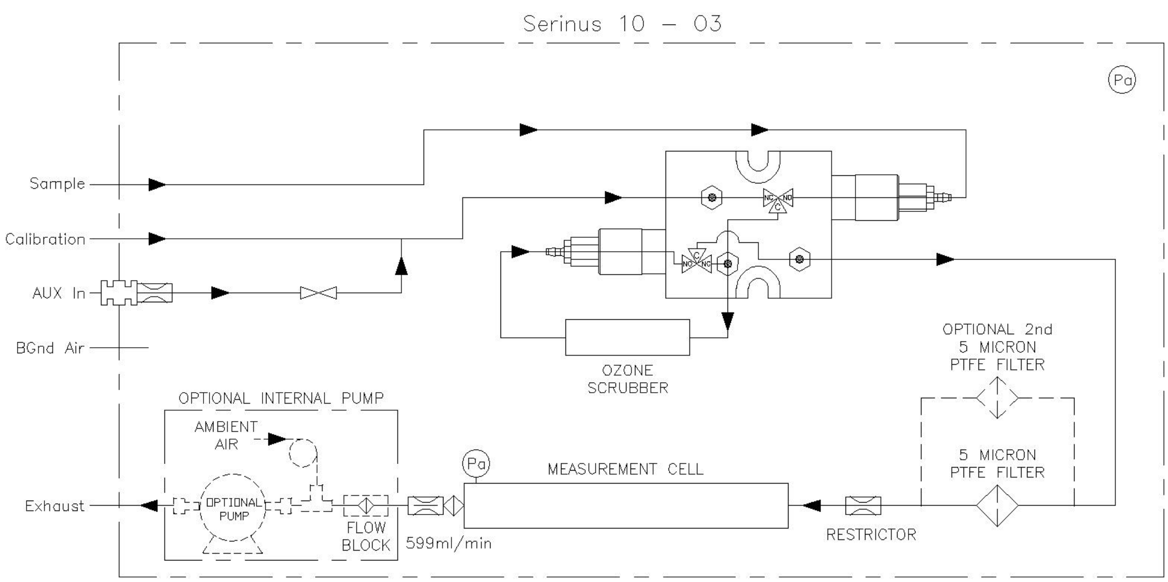


Figure 2: Pneumatic circuit diagram of the Serinus 10 measuring system

The major components of the Serinus 10 are described below:

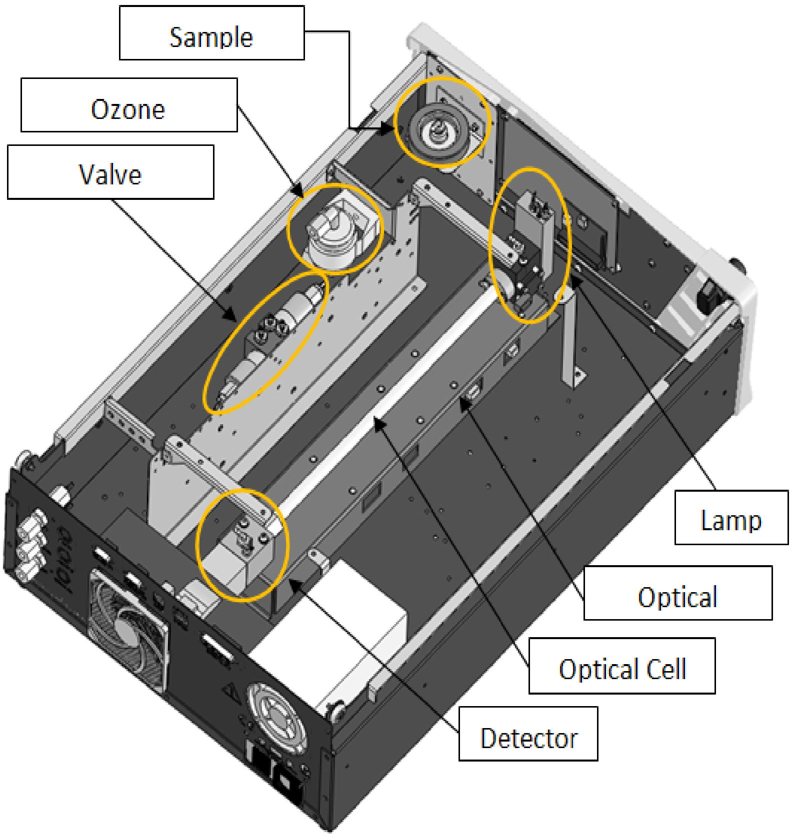


Figure 3: Internal components of the Serinus 10 measuring system

Figure 4: Internal view of the Serinus 10 measuring system

Particulate Filter
The particulate filter is a Teflon 5 micron (µm) filter with a diameter of 47 mm. This filter eliminates all particles larger than 5 µm that could interfere with sample measurements.

Ozone Scrubber
The ozone scrubber uses manganese dioxide (MnO_2) to selectively destroy ozone by catalytic means from the sample air while all other interferents remain. The ozone scrubber is used to remove any effects interferents might have on the final O_3 measurement by calculating their UV absorption and subtracting it from the O_3 measurement.

Valve Manifold
The instrument features a three way valve manifold to enable selection of either, external calibration gas, ambient air, or O_3-free ambient air.

Optical Bench
The optical bench consists of the lamp, detector, and optical cell.

Lamp
The UV light source is a mercury vapour lamp that emits radiation at a wavelength of 254 nm.

Lamp Driver PCB
The driver uses a high voltage and high frequency switching supply to start and maintain the UV lamp at a constant intensity. The lamp current is set by the microprocessor and is maintained at 10 mA. The lamp driver PCB is located under the UV absorption cell.

Lamp Power Supply
The high frequency lamp driver is set for 10 mA power output at 800 – 1100 volts. The correct setting must be used otherwise the electronics will be damaged. For the Serinus 10 (which measures O_3) switches 1 & 2 must be in the “OFF” position, and switches 3 & 4 must be in the “ON” position.

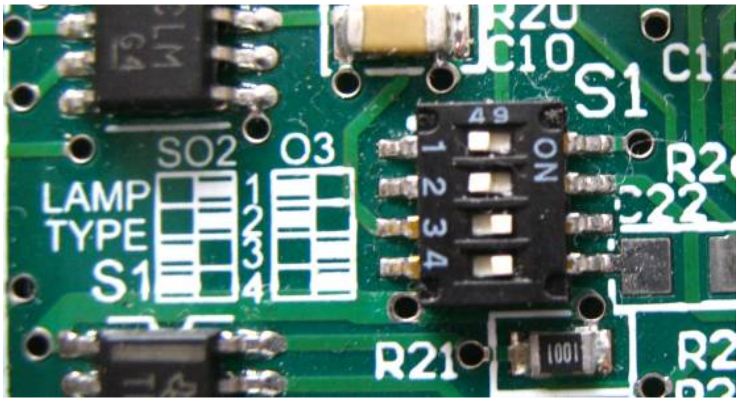


Figure 5: Lamp type switch setting

Optical Cell
The optical cell is a glass tube with a UV source at the one end and a detector at the other. UV radiation is absorbed sequentially by the sample gas and the ozone free sample gas over the length of the reaction cell. The remaining light reaching the detector is measured and used to calculate the O_3 concentration.

Detector
The detector is a solar blind vacuum diode sensitive only in the spectral region where O_3 absorbs (254 nm). This sensor is used to monitor the intensity of the residual light after absorption in the reaction cell. The UV detector preamplifier converts the detector’s current output into a voltage level for the main PCB A/D converter.

Main Controller PCB
The main controller PCB controls all the processes within the instrument. It contains a battery backed clock, calendar and an on board microprocessor. The main controller PCB is located on top of the other components within the analyser. The PCB pivots on hinges to allow access to the components underneath.

Pressure PCB
The pressure PCB contains an absolute pressure transducer to measure cell pressure. The sample pressure is used by the CPU to calculate both the O_3 concentration and cell flow rate.

Power Supply
The power supply is a self-contained unit housed in a steel case.
It has a selectable input voltage of 115 or 230 VAC 50/60 Hz and an output voltage of 12 VDC for distribution within the analyser.

On/Off Switch
The on/off switch is located on the back panel (bottom right facing from behind the instrument).

Communications
The analyser can be connected to a data logger, a laptop computer or a network by means of the following communications connections located on the back panel of the instrument.

RS232 #1
This port is designed to be used for simple RS232 communication.

RS232 #2
This port is designed to be used for simple RS232 communication, or in multidrop configuration.

USB
This port is used for instrument communication. It allows for quickly downloading data, onsite diagnostics, maintenance as well as firmware upgrades.

TCP/IP (optional)
This port is best used for remote access and real-time access to instruments when a network is available to connect with.

External I/O Port
The analogue/digital sends and receives analogue/digital signals to/from other devices. These signals are commonly used to activate gas calibrators or for warning alarms.

Analogue Outputs
The analyser is equipped with three analogue outputs. Menu selectable as either voltage output (0-5 VCD) or current output 0-20, 2-20 or 4-20 mA.

Analogue Inputs
The analyser is also equipped with three analogue voltage inputs (0-5 VDC) with resolution of 15 bits plus polarity.

Digital Status Inputs
The analyser is equipped with 8 logic level inputs (0-5 VDC) for the external control of zero/span calibration sequences.

Digital Status Outputs
The analyser is equipped with 8 open collector outputs which will convey instrument status conditions and warning alarms such as “no flow”, “sample mode”, etc.

Bluetooth
This allows for remote access of the analyser to any Android device with the “Serinus Remote” application installed on it. The application uses Bluetooth to control the analyser, view parameters, download data and construct real-time graphs.

Sample Gas Pump

Manufacturer: Thomas, type: 617CD22-194 C

During performance testing the above-mentioned sample gas pump was used in the laboratory as well as in the field test. As far as the models Serinus 10 (ozone), Serinus 30 (CO) and Serinus 50 (SO_2) are concerned, one pump can be operated with up to two analysers. However, for the Serinus 40 (NO_X) one sample gas pump per analyser is required.

measuring system

Table 2 provides a list with important technical features of the Serinus 10 measuring system

Table 2: Technical data of the Serinus 10 measuring system (as provided by the manufacturer)

Measuring range:	Max. 0 – 20 ppm (programmable)
Units:	ppb, ppm, mg/m³, µg/m³
Measured compound:	Ozone
Sample flow rate:	approx. 0.5 litres/min
Output signals:	• USB port on the back side • Bluetooth (digital communication via Android Application) • TCP/IP Ethernet network connection (optional) • RS232 port #1: digital communication or termination panel connections • RS232 port #2: multidrop port used for multiple analyser connections on a single RS232 • USB flash memory (front panel) for data logging, event logging and parameters/configuration storage
Protocols:	Modbus RTU/TCP, Bavarian, EC9800, Advanced
Power supply:	99 V – 132 V, 57 Hz – 63 Hz or 198 V – 264 V, 47Hz – 53 Hz
Consumption:	max. 85 W
Dimensions (L x B x H) / weight:	597 x 418 x 163 mm / 17.2 kg

4. Test program

4.1 General

Performance testing was carried out with two complete and identical instruments with the serial numbers

System 1: SN 13-0091 and
System 2: SN 13-0090.

During the test software version 2.09.0005 was implemented.

Performance testing consisted of a laboratory test to determine the performance characteristics and a field test that lasted several months.

This report presents a heading for each test criterion along with the number and description as stipulated in the respective standard [1. 2. 3. 4].

4.2 Laboratory test

The laboratory test was carried out with two identical Serinus 10 measuring systems with the serial numbers SN: 13-0091 and SN: 13-0090. In accord with the guidelines [2, 3] the following performance criteria were tested:

- Description of operating states
- General requirements
- Adjustment of the calibration line
- Short-term drift
- Repeatability standard deviation
- Sensitivity coefficient of the sample gas pressure
- Sensitivity coefficient of surrounding temperature
- Sensitivity coefficient of supply voltage
- Cross-sensitivities
- Response time
- Difference between sample and calibration port

Instrument readings were recorded using an external data logger.

Results obtained during the laboratory tests are summarised in section 6.

4.3 Field test

The field test was carried out with two complete and identical Serinus 10 measuring systems and lasted from 03 July 2013 to 04 October 2013. The measuring systems under test were identical to those used during laboratory testing. The serial numbers are as follows:

System 1: SN 13-0091
System 2: SN 13-0090

The following performance criteria were tested during the field test:

- Long-term drift
- Maintenance interval
- Availability
- Reproducibility standard deviation under field conditions

5. Reference measurement method

Test gases used to adjust the analyser during the test (systems under test and TÜV measuring systems)

In order to generate the test concentrations for ozone, an ozone generator manufactured by MCZ was employed. To check the generated ozone concentrations, the method was analysed according to guidelines ISO 13964 “Determination of ozone in ambient air” and VDI 2468 Sheet 6 “Measurement of ozone, direct UV-photometric method (Standard method)”. Prior to the testing, the ozone generator used was itself validated against a primary UV calibration photometer which is based on the national reference laboratory.

Zero gas:	Synthetic air
Ozone generator:	Manufacturer: MCZ
	Type: MK5
Serial number:	0409-086
Checking of the certificate by / on:	UBA Langen / 16 April 2013

6. Test results according to VDI 4203 Sheet 3

6.1 4.1.1 Measured value display

The measuring system shall be fitted with a measured value display.

6.2 Equipment

No additional equipment is required.

6.3 Testing

It was checked whether the measuring system has a measured value display.

6.4 Evaluation

The measuring system has a measured value display.

6.5 Assessment

The measuring system is fitted with a measured value display.
Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 4.1.2 Easy maintenance

Necessary maintenance of the measuring system should be possible without larger effort, if possible from outside.

6.2 Equipment

No additional equipment is required.

6.3 Testing

The necessary regular maintenance tasks were performed in accordance with the instruction manual.

6.4 Evaluation

The user shall perform the following maintenance tasks:

1. Checking of the instrument status
   The status of the instrument can be checked and monitored by way of visual inspection of the display.
2. Checking and replacing the particulate filter at the sample gas inlet.
   The frequency with which particulate filters need to be replaced depends on the dust concentration in the ambient air.

6.5 Assessment

Maintenance can be carried out with usual tools in a reasonable time and from the outside.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Maintenance tasks were performed during the test and in accordance with the tasks and procedures described in the manual. Complying with these procedures, no difficulties were identified. Until now all maintenance tasks were performed easily by means of usual tools.

6.1 4.1.3 Functional check

If the operation or the functional check of the measuring system require particular instruments, they shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.
Test gas units included in the measuring system shall indicate their operational readiness to the measuring system by a status signal and shall provide direct as well as remote control via the measuring system.

6.2 Equipment

Manual

6.3 Testing

The tested instrument does not have an internal device for functional checks. The operational status of the AMS is continually monitored and potential problems are displayed via an array of different error messages.

The functional check was performed with external test gases.

6.4 Evaluation

The tested instrument does not have an internal device for functional checks. The operational status of the AMS is continually monitored and potential problems are displayed via an array of different error messages.

It is possible to perform external zero point and span point checks by means of test gases.

6.5 Assessment

The tested instrument does not have an internal device for functional checks.

Does this comply with the performance criterion? not applicable

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 4.1.4 Set-up times and warm-up times

The set-up times and warm-up times shall be specified in the instruction manual.

6.2 Equipment

The testing of this performance criterion requires the additional provision of a clock.

6.3 Testing

The measuring systems were put into operation in accordance with the specifications provided by the manufacturer. The set-up times and warm-up times needed were recorded separately.

Required structural measures prior to AMS installation such as the setup of a sampling system in the analytics room were not assessed here.

6.4 Evaluation

The manual does not provide information on the set-up times. It is evident that this would depend on the specific conditions of the measurement site as well as on the voltage supply available. As the Serinus 10 measuring system is a compact analyser, the set-up time is mainly comprised of:

- Establishing the voltage supply
- Connecting necessary tubes (sampling, exhaust air)

A set-up time of approx. 0.5 h was determined for various changes in positions in the laboratory (i.e. installation/dismounting in the climate chamber) and installation in the field.

When switched on from a completely cold state the instrument requires approx. 60 minutes until the reading stabilises.

The measuring system has to be mounted at a place where it is protected from changes in the weather, for instance in an air conditioned measuring container.

6.5 Assessment

Set-up times and warm-up times were determined.

The measuring system may be operated at different measurement sites without undue effort. The time required for setting up the system is approx. 0.5 h and the warm-up time amounts to 1–2 h depending on the time required for stabilisation.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 4.1.5 Instrument design

The instruction manual shall include specifications of the manufacturer regarding the design of the measuring system. The main elements are:
instrument shape (e.g. bench mounting, rack mounting, free mounting)
mounting position (e.g. horizontal or vertical mounting)
safety requirements
dimensions
weight
power consumption.

6.2 Equipment

Testing was performed using a measuring instrument for the determination of the power consumption as well as weighing scales.

6.3 Testing

The set-up of the provided instruments was compared to the description in the instruction manuals. The power consumption was determined for 24 h during normal operation in the field test.

6.4 Evaluation

The measuring system has to be mounted horizontally (e.g. on a table or in a rack) and protected against weather. The temperature at the installation site may not exceed the range of 0 °C to 30 °C.

The dimensions and weight of the measuring system correspond to the specifications in the instruction manual.

According to the manufacturer, the power consumption of the measuring system is 85 W (at maximum). In a 24-h test the overall power consumption was determined. The power consumption as specified by the manufacturer was not exceeded at any time during the test.

6.5 Assessment

The specifications of the manual with regard to instrument design are complete and correct.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not required in terms of this criterion.

6.1 4.1.6 Unintended adjustment

It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation.

6.2 Equipment

No additional equipment is required to test this performance criterion.

6.3 Testing

The measuring system may be operated using the display and control panel on the front side of the instrument or from an external computer connected to the RS232 or Ethernet ports.

The instrument does not have a built-in mechanism (password protection) to protect it against unintended or unauthorized re-adjustment. Changing parameters or adjusting sensors is only possible by pushing several sequences of keys.

As the system may not be set up outside, protection against unintended or unauthorised re-adjustment will have to be ensured by mounting the instrument at places where it is not possible to gain unauthorised access (e.g. locked measuring container / measuring cabinet).

6.4 Evaluation

Instrument parameters which affect measurement characteristics need to be typed in manually in complex key sequences (up-/down keys) and confirmed. It is not possible to make unintended adjustments.

In order to protect the measuring system against unauthorised adjustments it has to be mounted in a lockable environment (container/ cabinet).

6.5 Assessment

The measuring system itself is not protected against the unintended or unauthorised adjustment of instrument parameters. It has to be operated in a lockable measuring container.

Does this comply with the performance criterion? no

6.6 Detailed presentation of test results

Not required in terms of this criterion.

6.1 4.1.7 Data output

The output signals shall be provided digitally (e.g. RS232) and/or as analogue signals (e.g. 4mA to 20 mA).

6.2 Equipment

PC and network connection

6.3 Testing

The measuring system is equipped with RS232, USB, 25-pin digital and analogue in- and outputs, TCP/IP Ethernet network connection (optional) and Bluetooth. Moreover, it has a means to output analogue signals (max. 3 analogue outputs).

6.4 Evaluation

Measured signals are output at the back of the system as follows:

Analogue:	0 – 20, 2 – 20, 4 – 20 mA or 0 – 5 V, selectable concentration range
Digital	RS232, USB, 25-pin digital in- and outputs, TCP/IP Ethernet network connection (optional) and Bluetooth

6.5 Assessment

Measured signals are provided in analogue (0-20 mA, 2-20 mA, 4-20 mA or 0-5 V) and digital form (via TCP/IP, RS232, USB; Bluetooth).

It is possible to connect additional measuring systems or peripheral devices via the respective ports (e.g. analogue inputs).

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Figure 6 shows the rear side of the instrument with its different data outputs.

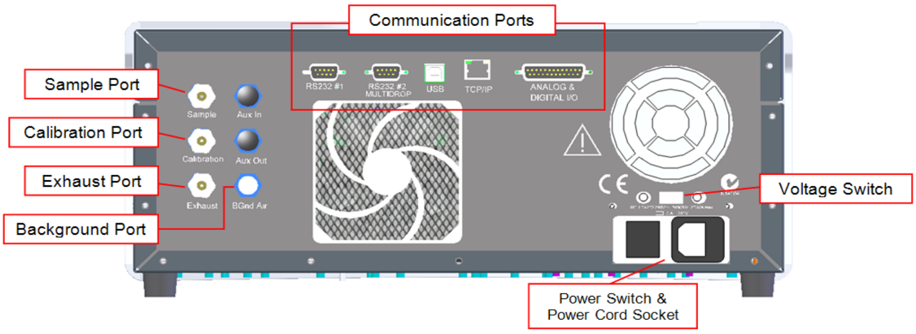


Figure 6: Rear panel of the Serinus 10

6.1 5.1 General

The manufacturer's specifications in the instruction manual shall be by no means better than the results of the performance test.

6.2 Equipment

Not required for this criterion.

6.3 Testing

The test results were compared to the specifications in the instruction manual.

6.4 Evaluation

Discrepancies between the first draft of the manual and the actual instrument design have been corrected.

6.5 Assessment

No discrepancies between the instrument design and the instruction manuals were observed.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.2.1 Certification range

The certification range intended for testing shall be determined.

6.2 Equipment

No additional equipment is required to test this performance criterion.

6.3 Testing

The certification range intended for testing shall be determined.

6.4 Evaluation

VDI Guideline 4202 Sheet 1 and Standard EN 14211 stipulate the following minimum requirements for the certification ranges of continuous ambient air monitoring systems for nitrogen dioxide:

Table 3: Certification range VDI 4202 Sheet 1 and DIN EN 14625

Measured component	Lower limit CR	Upper limit CR	Limit value (alert threshold)	Assessment period
	in µg/m³	in µg/m³	in µg/m³	
Ozone	0	500	240	1 h

6.5 Assessment

The measuring system can be assessed in the range of the relevant limit values.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.2.2 Measuring range

The upper limit of measurement of the measuring systems shall be greater or equal to the upper limit of the certification range.

6.2 Equipment

No additional equipment is required to test this criterion.

6.3 Testing

It was determined whether the upper limit of the measuring range was greater or equal to the upper limit of the certification range.

6.4 Evaluation

In principle, the measuring system allows for measuring ranges from max. 0 – 20 ppm.

Possible measuring range:	20 ppm
Upper limit of the certification range for ozone:	500 µg/m³

6.5 Assessment

By default the measuring range is set to 0 – 500 µg/m³ for ozone. Other measuring ranges of max. 0 – 20 ppm are possible.

The upper limit of the measuring range is larger than the respective upper limit of the certification range.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.2.3 Negative output signals

Negative output signals or measured values may not be suppressed (life zero).

6.2 Equipment

No additional equipment is required to test this performance criterion.

6.3 Testing

It was tested, in the laboratory and in the field, whether the measuring system displays negative signals.

6.4 Evaluation

The measuring system also displays negative measured values.

6.5 Assessment

The measuring system also displays negative measured values.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.2.4 Failure in the mains voltage

In case of malfunction of the measuring system or failure in the mains voltage for a period of up to 72 h, uncontrolled emission of operation and calibration gas shall be avoided. The instrument parameters shall be secured by buffering against loss caused by failure in the mains voltage. When mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement according to the operating instructions.

6.2 Equipment

No additional equipment is required to test this performance criterion.

6.3 Testing

A failure in the mains voltage was simulated in order to check whether the instrument remains intact and is ready to measure when mains voltage returns.

6.4 Evaluation

The measuring system does not require any operation or calibration gases. Thus, there is no uncontrolled emission of gases in the case of failure in the mains voltage.

In the event of power failure the measuring system will switch to warm-up mode when the power supply is re-established. It will remain in this mode until an appropriate and stable temperature for operation is reached. The time required for warm-up depends on the surrounding conditions at the installation site and on the thermal condition of the instrument itself when switched on again. After warm-up the instrument automatically switches back to the same mode that was active when the power failure occurred. The warm-up phase is indicated by a number of temperature alarms.

6.5 Assessment

When mains voltage returns the measuring system goes back to a failure-free operational status and automatically resumes measuring.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.2.5 Operating states

The measuring system shall allow control of important operating states by telemetrically transmitted status signals.

6.2 Equipment

PC for data recording.

6.3 Testing

The measuring system has various interfaces such as RS232, USB, 25-pin digital and analogue inputs and outputs, TCP/IP Ethernet network connection (optional) and Bluetooth. By means of the “Serinus Downloader” software a connection between the analyser and an external PC can be established. This software enables telemetrical data transfer, calibration of the analyser and by choosing the menu item “Remote Screen”, the analyser display is shown on the connected PC. In this mode, all information and functions shown on the analyser display can be accessed and controlled. Moreover, the “Remote Terminal” is a useful tool to check operation and parameter values. The manufacturer also provides the “Serinus Remote” Application which enables a connection between Android devices (tablet computers or smartphones) and the analyser.

6.4 Evaluation

The measuring system allows for extensive telemetrical monitoring and control via various connectivity options. The “Serinus Downloader” software is a helpful too for data transfer and remote control of the measuring system.

6.5 Assessment

By means of various connectivity options and the “Serinus Downloader” software the measuring system can be monitored and controlled from an external PC.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.2.6 Switch-over

Switch-over between measurement and functional check and/or calibration shall be possible telemetrically by computer control or manual intervention.

6.2 Equipment

No additional equipment is required to test this performance criterion.

6.3 Testing

The measuring system may be monitored or controlled via the control panel of the analyser or telemetrically via remote control.

6.4 Evaluation

All control functions which do not require direct on-site intervention may be performed by operating staff on-site or telemetrically via remote control.

6.5 Assessment

In general, all necessary tasks related to functional checks may be performed directly on-site or monitored telemetrically using the remote control functions.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.2.7 Maintenance interval

The maintenance interval of the measuring system shall be determined during the field test and specified. The maintenance interval should be three months, if possible, but at least two weeks.

6.2 Equipment

No additional equipment is required to test this performance criterion.

6.3 Testing

In testing this performance criterion, the types of maintenance work and the corresponding maintenance intervals needed to ensure proper functioning of the measuring system were determined. Moreover, drift behaviour of zero/span point according to 7.1 8.5.4 Long-term drift was taken into consideration in determining the maintenance interval.

6.4 Evaluation

During the entire field test period, no excessive drift behaviour was observed in the measuring systems. The maintenance interval is therefore determined by the necessary maintenance tasks.

During operation, maintenance tasks are generally limited to contamination and plausibility checks as well as checking for potential status signals and error warnings.

6.5 Assessment

As determined by the necessary maintenance tasks the maintenance interval is 4 weeks.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.2.8 Availability

The availability of the measuring system shall be determined during the field test and shall be at least 95%.

6.2 Equipment

No additional equipment is required to test this performance criterion.

6.3 Testing

The start and end time of the availability test are determined by the start and end time at the field test site. To this effect any interruptions of the test, for instance due to malfunctions or maintenance work, are recorded.

6.4 Evaluation

The field test was carried out in the period from 03 July 2013 to 04 October 2013. Thus, the measuring systems were tested in the field for 94 days in total. Table 4 lists periods of operation, maintenance and malfunction.

No malfunctions were observed.

6.5 Assessment

Availability for both systems was 100 % incl. maintenance times during testing.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Table 4: Determination of availability

		System 1 (SN 13-0091)	System 2 (SN 13-0090)
Operating time	h	2248	2248
Down time	h	0	0
Maintenance time	h	15	15
Effective operating time	h	2233	2233
Effective operating time incl. maintenance	h	2248	2248
Availability	%	100	100

6.1 5.2.9 Instrument software

The version of the instrument software to be tested shall be displayed during switch-on of the measuring system. The test institute shall be informed on changes in the instrument software, which have influence on the performance of the measuring system.

6.2 Equipment

No additional equipment is required to test this performance criterion.

6.3 Testing

It was verified whether the instrument displays its current software version upon switch-on. The instrument manufacturer was advised to inform the test institute on any changes to the instrument software.

6.4 Evaluation

The current software version is displayed upon switch-on of the instrument. It may also be accessed at any time in the "configuration" menu.

The test was performed while software version 2.09.0005 was in use.

6.5 Assessment

The instrument software version is indicated in the display. Changes to the software will be communicated to the test institute.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

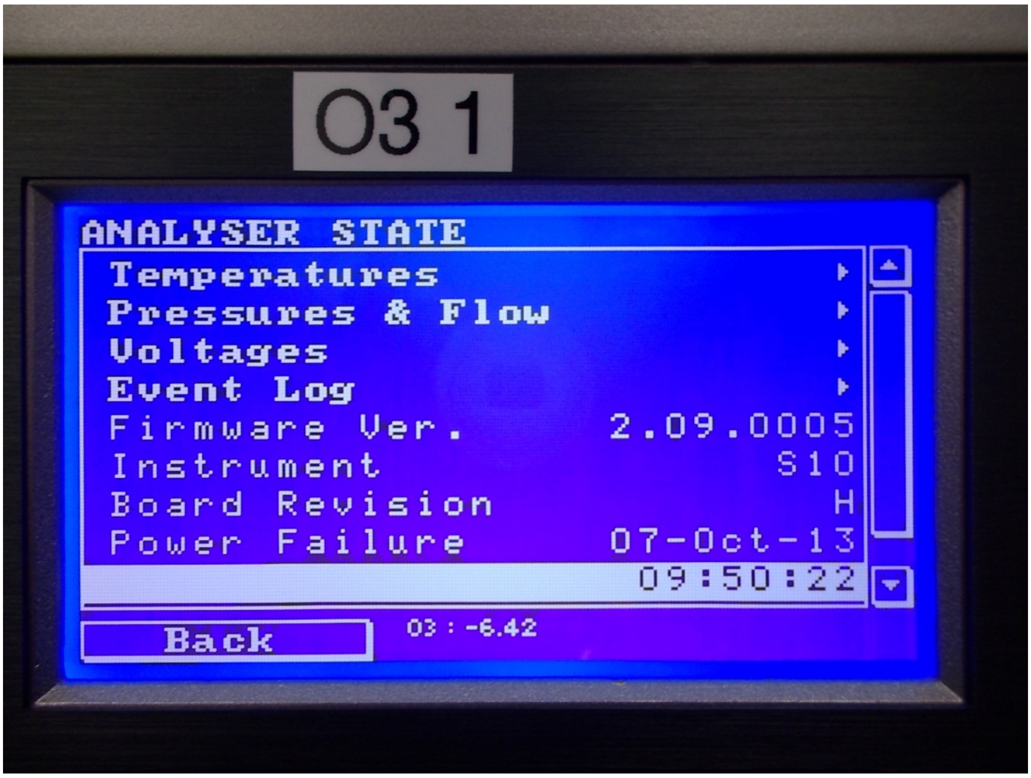


Figure 7: Display of the software version (2.09.0005) on the start screen

6.1 5.3.1 General

The tests shall be performed on the basis of the minimum requirements as stipulated in VDI 4202, Sheet 1 (September 2010).

6.2 Equipment

No additional equipment is required to test this performance criterion.

6.3 Testing

The test is performed on the basis of the minimum requirements as stipulated in VDI 4202, Sheet 1 (September 2010) and Standard DIN EN 14625 (December 2012).

6.4 Evaluation

VDI Guideline 4202 Sheet 1 and VDI Guideline 4203 Sheet 3 were revised extensively and republished in an amended version in September 2010. Minimum requirements as listed in Table 2 a/b of said guideline were used for evaluation.

6.5 Assessment

The tests were performed on the basis of the minimum requirements as stipulated in VDI 4202, Sheet 1 (September 2010) as well as Standard DIN EN 14625 (2012).

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.2 Repeatability standard deviation at zero point

The repeatability standard deviation at zero at point shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010) in the certification range according to Table 1 of VDI 4202, Sheet 1 (September 2010).

In case of deviating certification ranges, the repeatability standard deviation at zero point shall not exceed 2 % of the upper limit of this certification range.

The repeatability standard deviation at zero point shall not exceed 1.0 nmol/mol (i.e. 2.0 µg/m³).

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the repeatability standard deviation at zero point are in line with the requirements stipulated in Standard DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.5 Repeatability standard deviation.

6.4 Evaluation

Please refer to section 7.1 8.4.5 Repeatability standard deviation.

6.5 Assessment

Please refer to section 7.1 8.4.5 Repeatability standard deviation.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.3 Repeatability standard deviation at reference point

The repeatability standard deviation at reference point shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010) in the certification range according to Table 1 of VDI 4202, Sheet 1 (September 2010). The limit value or the alert threshold shall be used as reference point.

In case of deviating certification ranges, the repeatability standard deviation at reference point shall not exceed 2 % of the upper limit of this certification range. In this case a value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.

The repeatability standard deviation at reference point shall not exceed 3.0 nmol/mol (i.e. 6.0 µg/m³).

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the repeatability standard deviation at reference point are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.5 Repeatability standard deviation.

6.4 Evaluation

Please refer to section 7.1 8.4.5 Repeatability standard deviation.

6.5 Assessment

Please refer to section 7.1 8.4.5 Repeatability standard deviation.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.4 Linearity (lack of fit)

The analytical function describing the relationship between the output signal and the value of the air quality characteristic shall be linear.

Reliable linearity is given, if deviations of the group averages of measured values about the calibration function meet the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010) in the certification range according to Table 1 of VDI 4202, Sheet 1 (September 2010).

For all other certification ranges the group averages of measured values about the calibration function shall not exceed 5 % of the upper limit of the corresponding certification range.
The deviation from the linear regression shall not exceed 4 %.

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the lack of fit are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.6 Lack of fit of linearity of the calibration function.

6.4 Evaluation

Please refer to section 7.1 8.4.6 Lack of fit of linearity of the calibration function.

6.5 Assessment

Please refer to section 7.1 8.4.6 Lack of fit of linearity of the calibration function.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.5 Sensitivity coefficient of sample gas pressure

The sensitivity coefficient of sample gas pressure at reference point shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used at reference point.

The sensitivity coefficient of sample gas pressure shall not exceed 2 (nmol/mol)/kPa (i.e. (4 µg/m³)/kPa).

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the sensitivity coefficient of sample gas pressure are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.7 Sensitivity coefficient to sample gas pressure.

6.4 Evaluation

Please refer to section 7.1 8.4.7 Sensitivity coefficient to sample gas pressure.

6.5 Assessment

Please refer to section 7.1 8.4.7 Sensitivity coefficient to sample gas pressure.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.6 Sensitivity coefficient of sample gas temperature

The sensitivity coefficient of sample gas temperature at reference point shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010). A value c_t *at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.*
The sensitivity coefficient of sample gas temperature shall not exceed 1.0 (nmol/mol)/K (i.e. (2.0 µg/m³)/K).

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the sensitivity coefficient of sample gas temperature are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.8 Sensitivity coefficient to sample gas temperature.

6.4 Evaluation

Please refer to section 7.1 8.4.8 Sensitivity coefficient to sample gas temperature.

6.5 Assessment

Please refer to section 7.1 8.4.8 Sensitivity coefficient to sample gas temperature.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.7 Sensitivity coefficient of surrounding temperature

The sensitivity coefficient of surrounding temperature at zero and reference point shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

The sensitivity coefficient of surrounding temperature shall not exceed 1.0 (nmol/mol)/K (i.e. (2.0 µg/m³)/K).

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the sensitivity coefficient of surrounding temperature are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.9 Sensitivity coefficient to the surrounding temperature.

6.4 Evaluation

Please refer to section 7.1 8.4.9 Sensitivity coefficient to the surrounding temperature.

6.5 Assessment

Please refer to section 7.1 8.4.9 Sensitivity coefficient to the surrounding temperature.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.8 Sensitivity coefficient of supply voltage

The sensitivity coefficient of supply voltage shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010). A value c_t *at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.*

The sensitivity coefficient of supply voltage shall not exceed 0.3 (nmol/mol)/V (i.e. (0.60 µg/m³)/V).

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the sensitivity coefficient of supply voltage are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.10 Sensitivity coefficient to electrical voltage.

6.4 Evaluation

Please refer to section 7.1 8.4.10 Sensitivity coefficient to electrical voltage.

6.5 Assessment

Please refer to section 7.1 8.4.10 Sensitivity coefficient to electrical voltage.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.9 Cross-sensitivity

The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010) at zero and reference point. The alert threshold (for ozone = 240 µg/m³) shall be used as reference point.
For measuring principles deviating from EN standards the absolute values of the sum of the positive and the sum of negative deviations caused by interfering components in the sample gas shall not exceed 3 % of the upper limit of the certification range at zero and reference point. A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine cross-sensitivities are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.11 Interferents.

6.4 Evaluation

Please refer to section 7.1 8.4.11 Interferents.

6.5 Assessment

Please refer to section 7.1 8.4.11 Interferents.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.10 Averaging effect

For gaseous components the measuring system shall allow the formation of hourly averages.

The averaging effect shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010).
The averaging effect shall not exceed 7 % of the measured value.

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the averaging effect are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section
7.1 8.4.12 Averaging test.

6.4 Evaluation

Please refer to section
7.1 8.4.12 Averaging test.

6.5 Assessment

Please refer to section
7.1 8.4.12 Averaging test

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.11 Standard deviation from paired measurements

The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test. It shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010).
The standard deviation under field conditions shall not exceed 5 % of the average over a period of 3 months.

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the standard deviation from paired measurements are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.5.5 Reproducibility standard deviation for ozone under field conditions.

6.4 Evaluation

Please see section 7.1 8.5.5 Reproducibility standard deviation for ozone under field conditions.

6.5 Assessment

Please see section 7.1 8.5.5 Reproducibility standard deviation for ozone under field conditions.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.12 Long-term drift

The long-term drift at zero point and reference point shall not exceed the requirements of Table 2 of VDI 4201, Sheet 1 (September 2010) in the field test. A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used at reference point.
The long-term drift at zero shall not exceed 5.0 nmol/mol (i.e. 10.0 µg/m³).
The long-term drift at span point shall not exceed 5 % of the upper limit of the certification range.

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the long-term drift are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.5.4 Long-term drift.

6.4 Evaluation

Please refer to section 7.1 8.5.4 Long-term drift.

6.5 Assessment

Please refer to section 7.1 8.5.4 Long-term drift.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.13 Short-term drift

The short-term drift at zero point and reference point shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010) within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test. A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.
The short-term drift at zero point shall not exceed 2.0 nmol/mol (i.e. 4.0 µg/m³).
The short-term drift at span point shall not exceed 6.0 nmol/mol (i.e. 12.0 µg/m³).

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the short-term drift are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.4 Short-term drift.

6.4 Evaluation

Please refer to section 7.1 8.4.4 Short-term drift.

6.5 Assessment

Please refer to section 7.1 8.4.4 Short-term drift.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.14 Response time

The response time (rise) of the measuring system shall not exceed 180 s.

The response time (fall) of the measuring system shall not exceed 180 s.

The difference between the response time (rise) and response time (fall) of the measuring system shall not exceed 10 % of response time (rise) or 10 s, whatever value is larger.

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the response time are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.3 Response time.

6.4 Evaluation

Please refer to section 7.1 8.4.3 Response time.

6.5 Assessment

Please refer to section 7.1 8.4.3 Response time.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.15 Difference between sample and calibration port

The difference between the measured values obtained by feeding gas at the sample and calibration port shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.
The difference between sample and calibration port shall not exceed 1 %.

6.2 Equipment

Not applicable here.

6.3 Testing

Performance and evaluation of the steps taken to determine the difference between sample and calibration port are in line with the requirements stipulated in DIN EN 14625 (2012). The reader is therefore referred to section 7.1 8.4.13 Difference sample/calibration port.

6.4 Evaluation

Please refer to section 7.1 8.4.13 Difference sample/calibration port.

6.5 Assessment

Please refer to section 7.1 8.4.13 Difference sample/calibration port.

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.16 Converter efficiency

In case of measuring systems with a converter, the converter efficiency shall be at least 98 %.

6.2 Equipment

Not applicable here.

6.3 Testing

Due to the measurement principle the tested measuring system does not use a converter.

6.4 Evaluation

Not applicable here.

6.5 Assessment

This test item does not apply as the measuring system does not use a converter.
Does this comply with the performance criterion? Not applicable

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.17 Increase of NO_2 concentrations due to residence in the measuring system

In case of NO_X measuring systems the increase of NO_2 concentration due to residence in the measuring system shall not exceed the requirements of Table 2 of VDI 4202, Sheet 1 (September 2010).

The requirements of Table 2 of VDI 4202, Sheet 1 (September 2010) apply to certification ranges according to Table 1 of VDI 4202, Sheet 1 (September 2010). For deviating certification ranges the requirements shall be proportionally converted.

6.2 Equipment

Not applicable here.

6.3 Testing

This test item does not apply as the tested measuring system does not measure NO_X.

6.4 Evaluation

Not applicable in this instance.

6.5 Assessment

Not applicable as the measuring system does not measure NO_X.

Does this comply with the performance criterion? not applicable

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.18 Overall uncertainty

The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives in the applicable EU Directives on air quality listed in Annex A, Table A1 of VDI 4202, Sheet 1 (September 2010).

6.2 Equipment

Not applicable here.

6.3 Testing

The determination of uncertainty was performed in accordance with DIN EN 14625 (2012) and is detailed in section 7.1 8.6 Total uncertainty in accordance with Annex E of DIN EN 14625 (2012).

6.4 Evaluation

The determination of uncertainty was performed in accordance with DIN EN 14625(2012) and is detailed in section 7.1 8.6 Total uncertainty in accordance with Annex E of DIN EN 14625 (2012).

6.5 Assessment

The determination of uncertainty was performed in accordance with DIN EN 14625(2012) and is detailed in section 7.1 8.6 Total uncertainty in accordance with Annex E of DIN EN 14625 (2012).

Does this comply with the performance criterion? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

7. Test results in accordance with DIN EN 14625 (2012)

7.1 8.4.3 Response time

Neither the response time (rise) nor the response time (fall) shall exceed 180 s. The difference between rise and fall response time shall not exceed 10 s.

7.2 Test procedure

The determination of the response time shall be carried out by applying to the analyser a step function in the concentration from less than 20 % to about 80 % of the maximum of the certification range of ozone and vice versa.

The change from zero gas to span gas and vice versa needs to be made almost instantaneously, with the use of a suitable valve. The valve outlet shall be mounted direct to the inlet of the analyser, and both zero gas and span gas shall have the same amount of gas in excess, which is vented by the use of a tee. The gas flows of both zero gas and span gas shall be chosen in such a way that the dead time in the valve and tee can be neglected compared to the lag time of the analyser system. The step change is made by switching the valve from zero gas to span gas. This event needs to be timed and is the start (t = 0) of the (rise) lag time according to Figure 8. When the reading is stable to 98 % of the concentration applied, the span gas can be changed to zero gas again; this event is the start (t = 0) of the (fall) lag time. When the reading is stable to 2 % of the concentration applied, the whole cycle as shown in Figure 8 is complete.

The elapsed time (response time) between the start of the step change and reaching 90 % of the analyser final stable reading of the applied concentration shall be measured. The whole cycle shall be repeated four times. The average of the four response times (rise) and the average of the four response times (fall) shall be calculated.

The difference in response times shall be calculated according to:

$$t_d = \bar{t}_r - \bar{t}_f$$

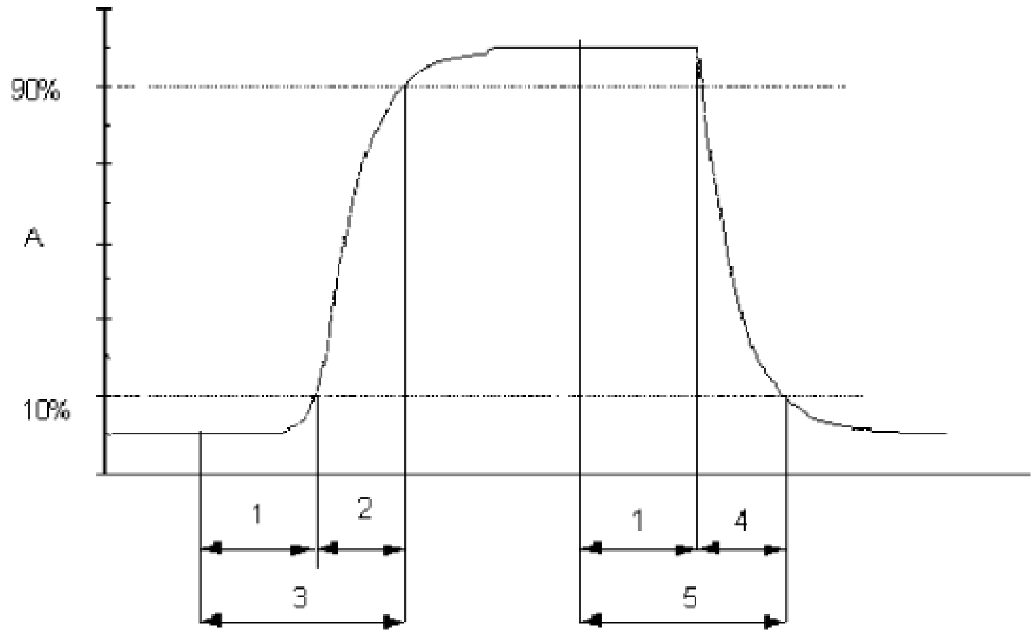
where

t_d is the difference between response time (rise) and response time (fall), in s;

t_r is the response time (rise) (average of the four response times - rise), in s;

t_f is the response time (fall (average of the four response times - fall), in s.

t_r, t_f and t_d shall comply with the performance criteria as specified above.



Key
A analyser response
1 lag time
2 rise time
3 response time (rise)
4 fall time
5 response time (fall)

Figure 8: Diagram illustrating the response time

7.3 Testing

The test was performed in accordance with the requirements on testing as stipulated in DIN EN 14625. Data were recorded using a Yokogawa DX2000 data logger with its averaging time set to 1 s.

7.4 Evaluation

Table 5: Response times of the two Serinus 10 measuring systems for ozone

	Requirement	Device 1		Device 2	
Average rise t_r [s]	≤ 180 s	44	✓	43	✓
Average fall t_f [s]	≤ 180 s	53	✓	51	✓
Difference t_d [s]	≤ 10 s	-9	✓	-7	✓

For system 1 this results in a maximum t_r of 44 s, a maximum t_f of 53 s and a t_d of -9 s for ozone.

For system 2 this results in a maximum t_r of 43 s, a maximum t_f of 51 s and a t_d of -7 s for ozone.

7.5 Assessment

The maximum permissible response time of 180 s is exceeded at no time. The maximum response time determined is 53 s for system 1 and 51 s for system 2.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Table 6: Individual readings for the response times for the component ozone

	80%	Device 1 Rise			Fall		
Concentration	200.00	0.0 0.00	0.9 180.00	1.0 200.00	1.0 200.00	0.1 20.00	0.0 0.00
Cycle 1	t = 0	10:32:10	10:32:45	10:43:30	10:55:10	10:56:10	10:56:30
	delta t		00:00:35			00:01:00	
	delta t [s]		35			60	
Cycle 2	t = 0	11:02:00	11:02:57	11:03:30	11:16:00	11:16:48	11:17:58
	delta t		00:00:57			00:00:48	
	delta t [s]		57			48	
Cycle 3	t = 0	12:04:00	12:04:40	12:07:35	12:20:20	12:21:35	12:21:45
	delta t		00:00:40			00:01:15	
	delta t [s]		40			75	
Cycle 4	t = 0	12:28:00	12:28:45	12:29:10	12:35:00	12:35:30	12:35:35
	delta t		00:00:45			00:00:30	
	delta t [s]		45			30	

	80%	Device 2 Rise			Fall		
Concentration	200.00	0.0 0.00	0.9 180.00	1.0 200.00	1.0 200.00	0.1 20.00	0.0 0.00
Cycle 1	t = 0	10:32:10	10:32:45	10:49:40	10:55:10	10:56:10	10:56:30
	delta t		00:00:35			00:01:00	
	delta t [s]		35			60	
Cycle 2	t = 0	11:02:00	11:02:53	11:10:38	11:16:00	11:16:48	11:16:55
	delta t		00:00:53			00:00:48	
	delta t [s]		53			48	
Cycle 3	t = 0	12:04:00	12:04:40	12:10:10	12:20:20	12:21:25	12:21:45
	delta t		00:00:40			00:01:05	
	delta t [s]		40			65	
Cycle 4	t = 0	12:28:00	12:28:45	12:29:05	12:35:00	12:35:30	12:35:35
	delta t		00:00:45			00:00:30	
	delta t [s]		45			30	

7.1 8.4.4 Short-term drift

The short-term drift at zero shall not exceed 2.0 nmol/mol/12h (i.e. 4.0 µg/m³/12h).

The short-term drift at span level shall not exceed 6.0 nmol/mol/12h (i.e. 12.0 µg/m³/12h).

7.2 Test procedure

After the required stabilisation period, the analyser shall be adjusted at zero and span level (around 70 % to 80 % of the maximum of the certification range of ozone). After waiting the time equivalent to one independent reading, 20 individual measurements are recorded, first at zero and then at span concentration. From these 20 measurements, the average is calculated for zero and span level.

The analyser shall be kept running under the laboratory conditions while analysing ambient air. After a period of 12 h, zero and span gas is fed to the analyser. After waiting the time equivalent to one independent reading, 20 individual measurements are recorded, first at zero and then at span concentration. The averages for zero and span level shall be calculated.

The short-term drift at zero and span level shall be calculated as follows:

$$D_{S,Z} = (C_{Z,2} - C_{Z,1})$$

where

$D_{S,Z}$ is the 12-hour-drift at zero, in nmol/mol;

$C_{Z,1}$ is the average concentration of the measurements at zero at the beginning of the drift period, in nmol/mol;

$C_{Z,2}$ is the average concentration of the measurements at zero at the end of the drift period, in nmol/mol.

$D_{S,Z}$ shall meet the performance criterion as specified above.

$$D_{S,S} = (C_{S,2} - C_{S,1}) - D_{S,Z}$$

where

$D_{S,S}$ is the 12-hour drift at span level, in nmol/mol;

$C_{S,1}$ is the average concentration of the measurements at span level at the beginning of the drift period, in nmol/mol;

$C_{S,2}$ is the average concentration of the measurements at span level at the end of the drift period, in nmol/mol

$D_{S,S}$ shall meet the performance criterion as specified above.

7.3 Testing

The test was performed in accordance with the requirements on testing as stipulated in DIN EN 14625. According to this standard, the test shall be performed using ozone at a concentration level of 70 % to 80 % of the certification range for ozone.

7.4 Evaluation

Table 7 lists the readings obtained for the short-term drift.

Table 7: Results for the short-term drift

	Requirement	Device 1		Device 2	
Averange at zero at the beginning [nmol/mol]	-	1.45		2.31	
Averange at zero at the end [nmol/mol]	-	1.93		1.28	
Averange at span at the beginning [nmol/mol]	-	187.72		185.00	
Averange at span at the end [nmol/mol]	-	190.09		185.87	
12-hour drift at zero $D_{s,z}$ [nmol/mol]	≤ 2.0	0.49	✓	-1.04	✓
12-hour drift at span $D_{s,s}$ [nmol/mol]	≤ 6.0	1.89	✓	1.91	✓

7.5 Assessment

The short term drift at zero is 0.49 nmol/mol for system 1 and -1.04 nmol/mol for system 2.

The short-term drift at span point is 1.89 nmol/mol for system 1 and 1.91 nmol/mol for system 2.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Individual test results are provided in Table 8 and Table 9.

Table 8: Individual test results for the short term drift, 1st test gas feeding

Start values			Start values		
Zero level			Span level		
	Device 1	Device 2		Device 1	Device 2
Time	[nmol/mol]	[nmol/mol]	Time	[nmol/mol]	[nmol/mol]
07:54:55	1.7	2.5	09:33:01	186.5	185.0
07:55:49	1.4	2.3	09:33:55	186.6	184.7
07:56:43	1.3	2.3	09:34:49	187.1	184.1
07:57:37	1.5	2.5	09:35:43	187.2	183.8
07:58:31	1.3	2.5	09:36:37	187.4	183.9
07:59:25	1.3	2.3	09:37:31	187.5	184.7
08:00:19	1.3	2.2	09:38:25	187.5	185.3
08:01:13	1.2	2.2	09:39:19	188.0	185.3
08:02:07	0.9	2.3	09:40:13	188.3	185.7
08:03:01	1.3	2.6	09:41:07	188.0	185.6
08:03:55	1.3	2.7	09:42:01	187.7	185.5
08:04:49	1.1	1.5	09:42:55	187.7	185.0
08:05:43	0.8	2.1	09:43:49	187.7	184.9
08:06:37	1.0	2.4	09:44:43	187.8	185.2
08:07:31	1.4	2.4	09:45:37	188.1	184.5
08:08:25	1.8	2.5	09:46:31	188.1	184.1
08:09:19	1.8	1.9	09:47:25	188.2	184.1
08:10:13	2.1	2.1	09:48:19	188.2	184.1
08:11:07	2.0	2.6	09:49:13	188.0	185.1
08:12:01	2.3	2.3	09:50:07	188.9	189.4
Average	**1.4**	**2.3**	**Average**	**187.7**	**185.0**

Table 9: Individual test results for the short term drift, 2nd test gas feeding

After 12h		
Zero level		
	Device 1	Device 2
Time	[nmol/mol]	[nmol/mol]
07:36:55	3.0	-0.5
07:37:49	2.8	0.1
07:38:43	2.4	-0.6
07:39:37	2.1	-1.3
07:40:31	1.9	-0.6
07:41:25	1.7	0.2
07:42:19	1.7	-0.3
07:43:13	1.6	-0.3
07:44:07	1.6	-0.1
07:45:01	1.8	0.4
07:45:55	1.9	1.6
07:46:49	1.8	2.6
07:47:43	2.1	2.7
07:48:37	2.1	2.4
07:49:31	1.8	2.6
07:50:25	1.6	3.4
07:51:19	1.6	3.8
07:52:13	1.7	3.8
07:53:07	1.9	3.6
07:54:01	1.9	2.2
Average	**1.9**	**1.3**

After 12h		
Span level		
	Device 1	Device 2
Time	[nmol/mol]	[nmol/mol]
08:38:07	188.8	182.8
08:39:01	189.2	183.2
08:39:55	189.5	183.5
08:40:49	190.0	184.4
08:41:43	190.0	184.1
08:42:37	189.9	183.5
08:43:31	190.1	183.3
08:44:25	190.0	184.7
08:45:19	189.9	185.2
08:46:13	190.2	185.7
08:47:07	190.4	186.4
08:48:01	189.6	187.5
08:48:55	189.9	187.7
08:49:49	190.5	188.1
08:50:43	190.9	188.4
08:51:37	191.1	188.0
08:52:31	190.9	188.4
08:53:25	190.7	188.0
08:54:19	190.5	187.7
08:55:13	189.9	187.1
Average	**190.1**	**185.9**

7.1 8.4.5 Repeatability standard deviation

The repeatability standard deviation shall neither exceed 1.0 nmol/mol (i.e. 2 µg/m³) at zero nor shall it exceed 3 nmol/mol (i.e. 6 µg/m³) of the test gas concentration at reference point.

7.2 Test procedure

After waiting the time equivalent of one independent reading, 20 individual measurements both at zero concentration and at a test concentration (c_t) similar to the hourly limit value shall be performed.

From these measurements, the repeatability standard deviation (s_r) at zero concentration and at concentration (c_t) (hourly alert threshold value) shall be calculated according to:

$$s_r = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

where

- s_r is the repeatability standard deviation, in nmol/mol;
- x_i the *i*th measurement, in nmol/mol;
- $\bar{x}$ is the average of the 20 measurements, in nmol/mol;
- n is the number of measurements, n = 20.

The repeatability standard deviation shall be calculated separately for both series of measurements (zero gas and concentration c_t).

s_r shall comply with the performance criterion in Table 1, both at zero and at the test concentration c_t (hourly limit value).

The repeatability standard deviation at zero is used in combination with the slope of the calibration function determined in 8.4.6 to calculate the detection limit of the analyser as:

$$l_{\det} = 3{,}3 \cdot \frac{s_{r,z}}{B}$$

where

- $l_{\det}$ is the detection limit of the analyser, in nmol/mol
- $s_{r,z}$ is the repeatability standard deviation at zero, in nmol/mol
- B is the slope of the calibration function determined according to Annex A using the data from 8.4.6.

7.3 Testing

The test was performed in accordance with the requirements on testing as stipulated in DIN EN 14625. In accordance with these requirements, the test needs to be performed using the component ozone. DIN EN 14625 specifies that the test shall be performed at a concentration level of approx. 120 nmol/mol ozone. According to VDI Guideline 4202, Sheet 1, the test of the repeatability standard deviation at span point shall be performed using the limit value.

7.4 Evaluation

Table 10 details the test results for the repeatability standard deviation.

Table 10: Repeatability standard deviation at zero and span point

	Requirement	Device 1		Device 2	
Repeatability standard deviation $s_{r,z}$ at zero [nmol/mol]	≤ 1.0	0.32	✓	0.60	✓
Repeatability standard deviation $s_{r,ct}$ at c_t [nmol/mol]	≤ 3.0	0.16	✓	0.40	✓
Detection limit [nmol/mol]		1.06		1.99	

7.5 Assessment

The repeatability standard deviation at zero point is 0.32 nmol/mol for system 1 and 0.60 nmol/mol for system 2. The repeatability standard deviation at reference point is 0.16 nmol/mol for system 1 and 0.40 nmol/mol for system 2.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Table 11 lists the results of the individual measurements.

Table 11: Individual test results for the repeatability standard deviation

Zero level		
	Device 1	Device 2
Time	[nmol/mol]	[nmol/mol]
10:29:00	1.9	3.9
10:30:00	2.0	3.9
10:31:00	1.9	4.1
10:32:00	2.0	4.1
10:33:00	2.3	4.2
10:34:00	2.3	4.2
10:35:00	2.5	4.4
10:36:00	2.5	4.4
10:37:00	2.7	5.0
10:38:00	2.8	5.3
10:39:00	3.1	5.3
10:40:00	2.8	5.5
10:41:00	2.7	5.8
10:42:00	2.7	5.6
10:43:00	2.5	5.3
10:44:00	2.5	4.8
10:45:00	2.5	4.4
10:46:00	2.2	4.4
10:47:00	2.3	4.5
10:48:00	2.3	4.5
Average	2.4	4.7

c_t level		
	Device 1	Device 2
Time	[nmol/mol]	[nmol/mol]
10:58:00	120.2	118.4
10:59:00	120.2	118.6
11:00:00	120.2	118.9
11:01:00	120.2	119.1
11:02:00	120.5	119.1
11:03:00	120.5	118.6
11:04:00	120.5	118.6
11:05:00	120.3	118.3
11:06:00	120.3	118.1
11:07:00	120.3	118.3
11:08:00	120.2	118.9
11:09:00	120.3	118.6
11:10:00	120.3	118.8
11:11:00	120.6	119.2
11:12:00	120.6	119.1
11:13:00	120.3	118.3
11:14:00	120.3	118.3
11:15:00	120.5	118.1
11:16:00	120.5	118.0
11:17:00	120.6	117.8
Average	120.4	118.5

7.1 8.4.6 Lack of fit of linearity of the calibration function

The lack of fit of the calibration function shall not exceed 5 nmol/mol (i.e. 10 µg/m³) at zero point and 4 % of the measured value at concentrations above zero.

7.2 Test procedure

The lack of fit of linearity of the calibration function of the analyser shall be tested over the range of 0 % to 95 % of the maximum of the certification range of ozone, using at least six concentrations (including the zero point). The analyser shall be adjusted at a concentration of about 90 % of the maximum of the certification range. At each concentration (including zero) at least five individual measurements shall be performed.

The concentrations shall be applied in the following sequence: 80 %, 40 %, 0 %, 60 %, 20 % and 95 %. After each change in concentration, at least four response times shall be taken into account before the next measurement is performed.

Calculation of the linear regression function and residuals shall be performed according to Annex A of DIN EN 14625. All the (relative) residuals from the linear regression function shall fulfil the criteria as stated above.

Establishing the regression line:

A regression line in the form of $Y_i = A + B * X_i$ is established through calculation of the function

$$Y_i = a + B(X_i - X_z)$$

To calculate the regression, all measuring points (including zero) are taken into account. The total number of measuring points *n* is equal to the number of concentration levels (at least six including zero) multiplied by the number of repetitions (at least five) at each concentration level.

The coefficient *a* is obtained from

$$a = \sum Y_i / n$$

where

- a is the average of the Y-values;
- Y_i is the individual Y-value;
- n is the number of measuring points

The coefficient *B* is obtained from

$$B = \left(\sum Y_i (X_i - X_z)\right) / \sum (X_i - X_z)^2$$

where

- X_z is the average of the X-values $\left(= \sum (X_i / n)\right)$
- X_i is the individual X-value

The function $Y_i = a + B (X_i – X_z)$ is converted to $Y_i = A + B * X_i$ through the calculation of *A*

$$A = a – B * X_z$$

The residuals of the averages of the calibration points (including the zero point) are calculated as follows.
The average value of each calibration point (including the zero point) at one and the same concentration c is calculated according to:

$$(Y_a)_c = \sum (Y_i)_c / m$$

where
- $(Y_a)_c$ is the average y-value at concentration level c;
- $(Y_i)_c$ is the individual y-value at concentration level c;
- M is the number of repetitions at one and the same concentration level c

The residual of each average (r_c) at each concentration level is calculated according to:

$$r_c = (Y_a)_c - (A + B \times c)$$

Each residual to a value relative to its own concentration level c is expressed in % as:

$$r_{c,rel} = \frac{r_c}{c} \times 100\%$$

7.3 Testing

The test was performed in accordance with the requirements on testing as stipulated in DIN EN 14625.

7.4 Evaluation

The following linear regressions are obtained:

Figure 9 and Figure 10 graphically summarise the results of the determination of the group averages for ozone.

Table 12: Deviations of the analytical function for ozone

	Requirement	Device 1		Device 2	
Largest value of the relative residuals r_{max} [%]	≤ 4.0	1.38	✓	1.16	✓
Residual at zero r_z [nmol/mol]	≤ 5.0	1.25	✓	1.50	✓

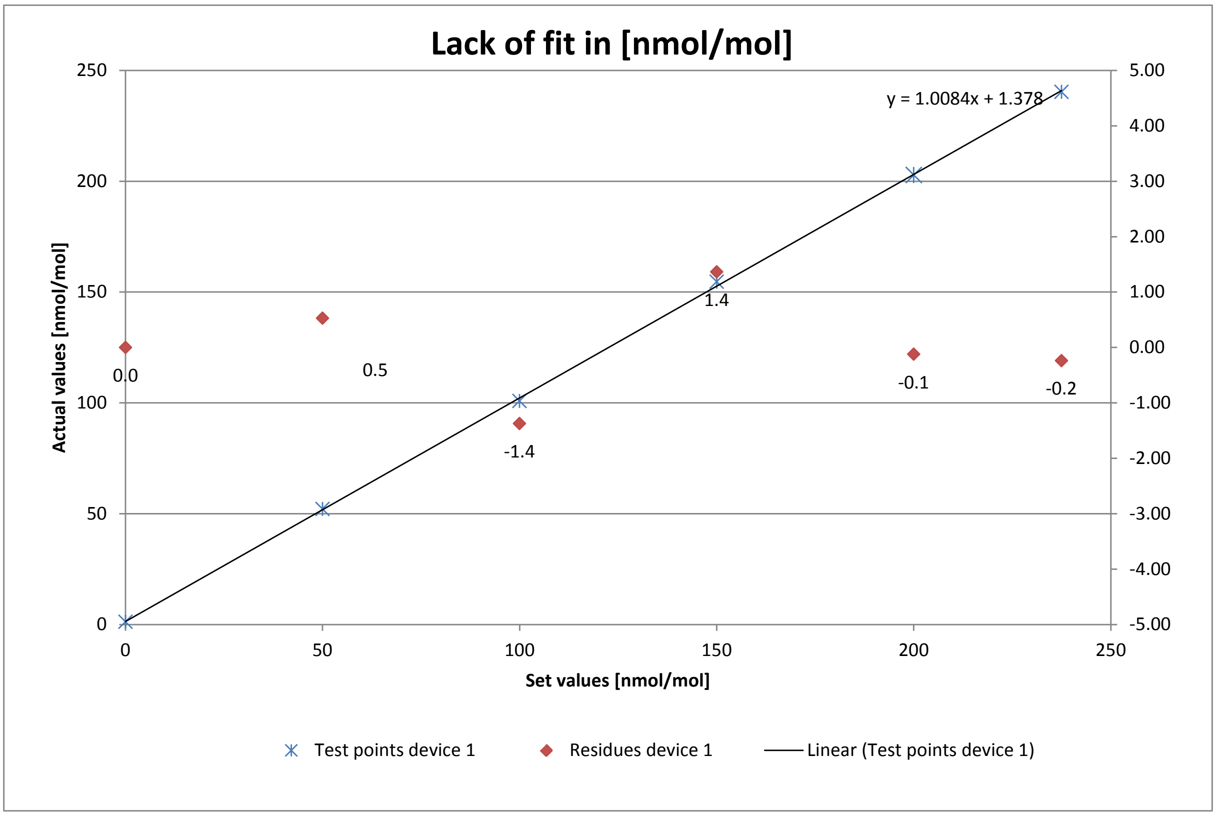


Figure 9: Function established from group averages for system 1, component ozone

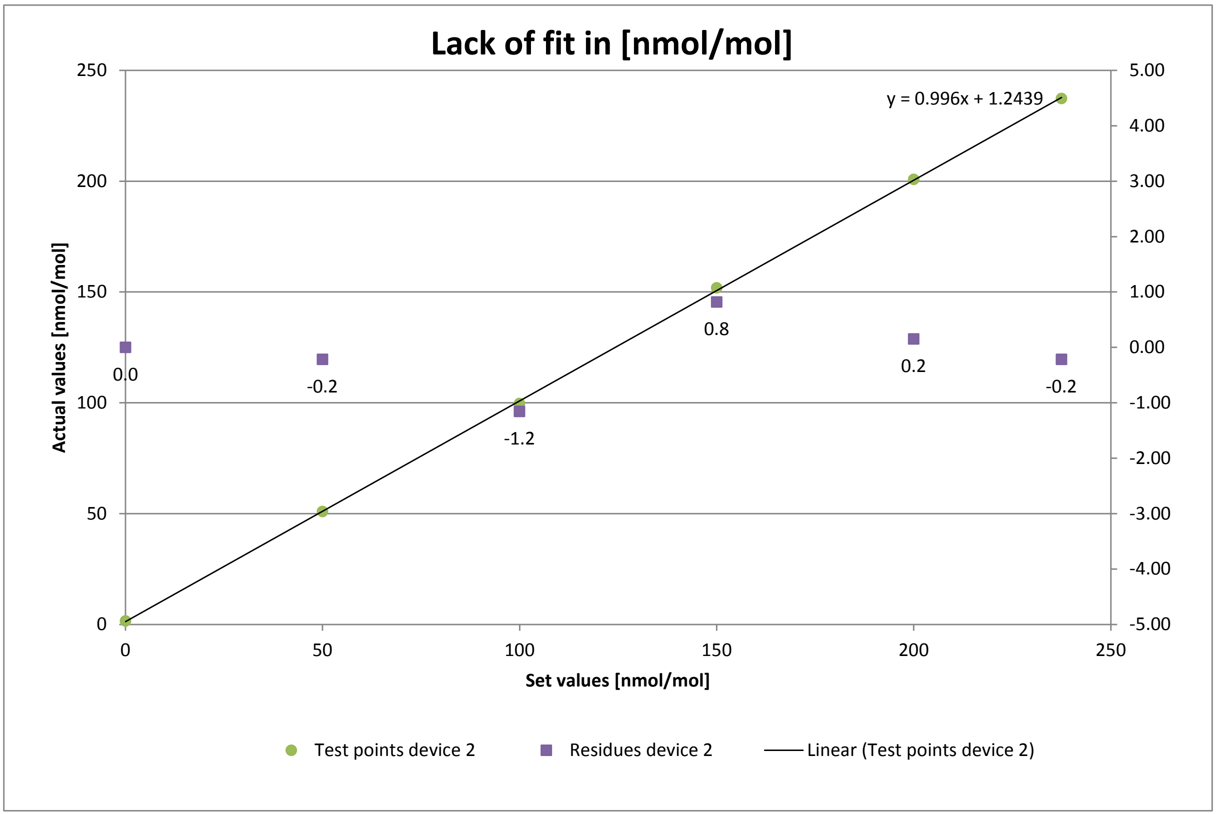


Figure 10: Function established from group averages for system 2, component ozone

7.5 Assessment

For system 1, the deviation from the regression line is 1.38 nmol/mol at zero point and max. 1.25 % of the target value for concentrations greater than zero. For system 2, the deviation from the regression line is 1.16 nmol/mol at zero and max. 1.50 % of the target value for concentrations greater than zero.

Deviations from the ideal regression line do not exceed the limit values stipulated in Standard DIN EN 14625.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Individual results are detailed in Table 13.

Table 13: Individual results pf the "lack of fit" test

		Device 1 [nmol/mol]		Device 2 [nmol/mol]	
Time	Level [%]	Actual value y_i	Set value x_i	Actual value y_i	Set value x_i
10:58:00	80	202.66	200.00	199.84	200.00
10:59:00	80	202.66	200.00	201.09	200.00
11:00:00	80	202.97	200.00	200.94	200.00
11:01:00	80	202.97	200.00	200.94	200.00
11:02:00	80	202.81	200.00	200.94	200.00
13:00:00	40	101.09	100.00	99.38	100.00
13:01:00	40	100.94	100.00	99.84	100.00
13:02:00	40	100.94	100.00	100.00	100.00
13:03:00	40	100.63	100.00	99.69	100.00
13:04:00	40	100.63	100.00	99.53	100.00
13:31:00	0	1.09	0.00	1.25	0.00
13:32:00	0	1.41	0.00	1.41	0.00
13:33:00	0	1.25	0.00	1.56	0.00
13:34:00	0	1.25	0.00	1.56	0.00
13:35:00	0	1.25	0.00	1.72	0.00
14:02:00	60	155.00	150.00	152.03	150.00
14:03:00	60	155.00	150.00	152.03	150.00
14:04:00	60	154.69	150.00	151.88	150.00
14:05:00	60	154.69	150.00	152.03	150.00
14:06:00	60	154.06	150.00	151.41	150.00
14:31:00	20	52.03	50.00	50.63	50.00
14:32:00	20	52.03	50.00	50.94	50.00
14:33:00	20	52.19	50.00	51.09	50.00
14:34:00	20	52.03	50.00	51.09	50.00
14:35:00	20	52.03	50.00	50.94	50.00
15:01:00	95	240.31	237.50	237.19	237.50
15:02:00	95	240.31	237.50	237.19	237.50
15:03:00	95	240.31	237.50	237.34	237.50
15:04:00	95	240.31	237.50	237.34	237.50
15:05:00	95	240.31	237.50	237.34	237.50

7.1 8.4.7 Sensitivity coefficient to sample gas pressure

The sensitivity coefficient to sample gas pressure shall not exceed 2.0 nmol/mol/kPa (i.e. 4.0 µg/m³/kPa).

7.2 Test procedure

Measurements are taken at a concentration of about 70 % to 80 % of the maximum of the certification range of ozone at an absolute pressure of about (80 kPa ± 0.2 kPa) and at an absolute pressure of about (110 kPa ± 0.2 kPa). At each pressure after waiting the time equivalent to one independent reading, three individual measurements are recorded. From these measurements, the averages at each pressure are calculated.

Measurements at different pressures shall be separated by at least four response times.

The sample gas pressure influence is calculated by:

$$b_{gp} = \left| \frac{(C_{P2} - C_{P1})}{(P_2 - P_1)} \right|$$

where

b_{gp} is the sample gas pressure sensitivity coefficient, in nmol/mol/kPa;

C_{P1} is the average concentration of the measurements at sampling gas pressure P_1, in nmol/mol;

C_{P2} is the average concentration of the measurements at sampling gas pressure P_2, in nmol/mol;

P_1 is the minimum sampling gas pressure P_1, in kPa;

P_2 is the maximum sampling gas pressure P_2, in kPa;

b_{gp} shall meet the performance criterion specified above.

7.3 Testing

The test was not performed in accordance in accordance with the requirements on testing as stipulated in Standard DIN EN 14625.

Negative pressuer was created by lowering the volume of inserted test gas by restricting the sampling line. For testing excess pressure, the analyser was connected to a test gas source. The generated test gas volume was greater than the sample gas volume sucked by the analysers. The excess gas is discharged via T piece. To generate excess pressure, the bypass line was restricted. The test gas pressure was determined by a pressure sensor within the test gas line.

Independent measurements are taken at concentrations of about 70 % to 80 % of the maximum of the certification range and sample gas pressures of 80 kPa and 110 kPa.

7.4 Evaluation

The following sensitivity coefficients for the influence of sample gas pressure were determined.

Table 14: Sensitivity coefficient to sample gas pressure

	Requirement	Device 1		Device 2	
Sensitivity coeff. sample gas pressure b_{gp} [nmol/mol/kPa]	≤ 2.0	0.06	✓	0.04	✓

7.5 Assessment

For system 1, the sensitivity coefficient to sample gas pressure is 0.06 nmol/mol/kPa.
For system 2, the sensitivity coefficient to sample gas pressure is 0.04 nmol/mol/kPa.
Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Table 15: Individual test results for the influence of changes in sample gas pressure

Time	Pressure [kPa]	Concentration	Device 1 [nmol/mol]	Device 2 [nmol/mol]
15:14:00	80	200.0	203.0	202.5
15:15:00	80	200.0	204.1	203.2
15:16:00	80	200.0	201.7	201.1
Average C_{P1}			202.9	202.2
15:49:00	110	200.0	201.0	201.9
15:50:00	110	200.0	202.1	200.5
15:51:00	110	200.0	200.4	200.6
Average C_{P2}			201.2	201.0

7.1 8.4.8 Sensitivity coefficient to sample gas temperature

The sensitivity coefficient to sample gas temperature shall not exceed 1.0 nmol/mol/K.

7.2 Test procedure

Measurements shall be performed at sample gas temperatures of T_1 = 0 °C and T_2 = 30 °C. A concentration around 70 % to 80 % of the maximum of the certification range of ozone shall be applied. After waiting the time equivalent to one independent measurement, three individual measurements at each temperature are recorded.

The sample gas temperature, measured at the inlet of the analyser, shall be held constant for at least 30 min.

The influence of sample gas temperature is calculated from:

$$b_{gt} = \frac{(C_{GT,2} - C_{GT,1})}{(T_{G,2} - T_{G,1})}$$

where

b_{gt} is the sample gas temperature sensitivity coefficient, in nmol/mol/°C

$C_{GT,1}$ is the average concentration of the measurements at sample gas temperature $T_{G,1}$, in nmol/mol;

$C_{GT,2}$ *i*s the average concentration of the measurements at sample gas temperature $T_{G,2}$, in nmol/mol;

$T_{G,1}$ is the minimum sample gas temperature $T_{G,1}$, in °C

$T_{G,2}$ is the maximum sample gas temperature $T_{G,2}$ in °C

b_{gt} shall meet the performance criterion specified above.

7.3 Testing

The test was performed in accordance with the requirements on testing as stipulated in DIN EN 14625.

For the purpose of the test, the sample gas mixture was conducted through a bundle of tubes of 20 m length, which was placed in a climate chamber. The measuring systems were set up directly in front of this chamber. The end of the bundle of tubes was connected to the measuring systems outside of the climate chamber with the opening being sealed. The test gas temperature was monitored by means of a thermocouple installed directly in front of the measuring systems. The temperature in the climate chamber was regulated so that the gas temperature at the inlets of the analysers was 0 °C. For checking the gas temperature at 30 °C, the gas was not conducted through the bundle of tubes in the climate chamber but through a tempered heating cable and then fed to the measuring systems.

7.4 Evaluation

Table 16: Sensitivity coefficient to sample gas temperature

	Requirement	Device 1		Device 2	
Sensitivity coeff. sample gas temperature b_{gt} [nmol/mol/K]	≤ 1.0	0.13	✓	0.14	✓

7.5 Assessment

For system 1, the sensitivity coefficient to sample gas temperature is 0.13 nmol/mol/K.
For system 2, the sensitivity coefficient to sample gas temperature is 0.14 nmol/mol/K.
Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Table 17: Individual values obtained from the determination of the influence of sample gas temperature for ozone

			Device 1	Device 2
Time	Temp [°C]	Concentration	[nmol/mol]	[nmol/mol]
10:20:00	0	187.50	189.53	184.53
10:20:56	0	187.50	189.06	185.63
10:21:52	0	187.50	189.06	184.06
Average $C_{GT,1}$			189.22	184.74
11:02:00	30	187.50	185.94	180.47
11:02:56	30	187.50	185.47	180.63
11:03:52	30	187.50	184.84	180.47
Average $C_{GT,2}$			185.42	180.52

7.1 8.4.9 Sensitivity coefficient to the surrounding temperature

The sensitivity coefficient to the surrounding temperature shall not exceed 1.0 nmol/mol/K.

7.2 Test procedure

The sensitivity of the analyser readings to the surrounding temperature shall be determined by performing measurements at the following temperatures (within the specifications of the manufacturer):

1) at the minimum temperature T_{min} = 0 °C;

2) at the temperature within the laboratory T_l = 20 °C;

3) at the maximum temperature T_{max} = 30 °C;

For these tests, a climate chamber is necessary.

A concentration around 70 % to 80 % of the maximum of the certification range of ozone shall be applied. At each temperature setting after waiting the time equivalent to one independent measurement, three individual measurements at zero and at span shall be recorded.

The sequence of test temperatures is as follows:

T_l, T_{min}, T_l and T_l, T_{max}, T_l

At the first temperature (T_l), the analyser shall be adjusted at zero and at span level (70 % to 80 % of the maximum of the certification range).Then three individual measurements are recorded after waiting the time equivalent to one independent reading at T_l, at T_{min} and again at T_l. This measurement procedure shall be repeated at the temperature sequence of T_l, T_{max} and T_l.

In order to exclude any possible drift due to factors other than temperature, the measurements at T_l are averaged, which is taken into account in the following formula for calculation of the sensitivity coefficient for temperature dependence:

$$b_{st} = \left| \frac{x_T - \frac{x_1 + x_2}{2}}{T_S - T_{S,0}} \right|$$

where

b_{st}	is the surrounding temperature sensitivity coefficient at zero or span and at T_{min} or T_{max} in nmol/mol/°C;
x_T	is the average of the measurements at T_{min} or $T_{max,}$ in nmol/mol;
x_1	is the first average of the measurements at $T_{1,}$ in nmol/mol;
x_2	is the second average of the measurements at $T_{1,}$ in nmol/mol;
T_S	is the extreme surrounding temperature at which the test is performed in the laboratory, in °C
$T_{S,0}$	is the average of the surrounding temperatures at set point, in °C

For reporting the surrounding temperature dependence the higher value is taken of the two calculations of the temperature dependence at $T_{S,1}$ or $T_{S,2}$.

b_{st} shall meet the performance criterion specified above.

7.3 Testing

The test was performed in accordance with the requirements on testing as stipulated DIN EN 14625.

7.4 Evaluation

The following sensitivity coefficients to the surrounding temperature resulted from the tests:

Table 18: Sensitivity coefficient to the surrounding temperature at zero point and span point, systems 1 and 2

	Requirement	Device 1		Device 2	
Sensitivity coefficient at 0 °C for zero level [nmol/mol/K]	≤ 1.0	0.188	✓	0.029	✓
Sensitivity coefficient at 30 °C for zero level [nmol/mol/K]	≤ 1.0	0.059	✓	0.031	✓
Sensitivity coefficient at 0 °C for span level [nmol/mol/K]	≤ 1.0	0.011	✓	0.066	✓
Sensitivity coefficient at 30 °C for span level [nmol/mol/K]	≤ 1.0	0.421	✓	0.206	✓

As illustrated in Table 18, the sensitivity coefficient to the surrounding temperature at zero point and at span point complies with the performance criteria..

7.5 Assessment

The sensitivity coefficient b_{st} to the surrounding temperature does not exceed the performance criteria of max. 1.0 nmol/mol/K. For both systems, the highest value b_{st} is used for the purpose of evaluating uncertainty. For system 1 it is 1 0.421 nmol/mol/K and for system 2 it is 0.206 nmol/mol/K.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Individual results of the tests are detailed in Table 19.

Table 19: Individual results of the test of the sensitivity to the surrounding temperature for ozone

	Zero level				Span level			
			Device 1	Device 2			Device 1	Device 2
Date	Time	Temp [°C]	[nmol/mol]	[nmol/mol]	Time	Temp [°C]	[nmol/mol]	[nmol/mol]
13/05/2013	15:58:31	20	0.1	1.9	17:02:25	20	185.4	180.1
13/05/2013	15:59:25	20	-0.3	0.9	17:03:19	20	185.8	180.1
13/05/2013	16:00:19	20	-0.2	1.5	17:04:13	20	186.0	180.4
Average ($X_{1(TS1)}$)			-0.1	1.4			185.7	180.2
14/05/2013	08:04:31	0	4.6	1.0	08:24:19	0	186.3	181.3
14/05/2013	08:05:25	0	4.8	1.0	08:25:13	0	186.9	181.6
14/05/2013	08:06:19	0	4.8	1.7	08:26:07	0	187.3	182.3
Average ($X_{Ts,1}$)		0	4.7	1.2			186.8	181.7
14/05/2013	14:52:31	20	1.4	1.8	15:21:19	20	187.3	184.8
14/05/2013	14:53:25	20	2.2	2.4	15:22:13	20	187.3	185.6
14/05/2013	14:54:19	20	2.6	2.5	15:23:07	20	187.8	187.3
Average ($X_{2(TS1)}$) = ($X_{1(TS2)}$)			2.1	2.2			187.5	185.9
15/05/2013	08:08:43	30	1.8	2.3	08:44:43	30	183.6	182.6
15/05/2013	08:09:37	30	1.9	1.9	08:45:37	30	183.2	182.8
15/05/2013	08:10:31	30	2.0	2.3	08:46:31	30	183.2	183.3
Average ($X_{Ts,2}$)			1.9	2.2			183.3	182.9
15/05/2013	14:31:37	20	2.8	1.9	15:14:49	20	187.1	184.3
15/05/2013	14:32:31	20	2.9	2.8	15:15:43	20	187.5	184.0
15/05/2013	14:33:25	20	2.9	3.5	15:16:37	20	188.3	184.1
Average ($X_{2(TS2)}$)			2.9	2.7			187.6	184.1

7.1 8.4.10 Sensitivity coefficient to electrical voltage

The sensitivity coefficient to electrical voltage shall not exceed 0.3 nmol/mol/V (i.e. 0.6 µg/m³/V).

7.2 Test procedure

The sensitivity coefficient of electrical voltage shall be determined at both ends of the voltage range specified by the manufacturer at zero concentration and at a concentration around 70 % to 80 % of the maximum of the certification range. After waiting the time equivalent to one independent measurement, three individual measurements at each voltage and concentration level shall be recorded.

The voltage dependence in accordance with Standard DIN EN 14625 is calculated from:

$$b_v = \left| \frac{(C_{V2} - C_{V1})}{(V_2 - V_1)} \right|$$

where

- b_v is the voltage sensitivity coefficient, in nmol/mol/V;
- C_{V1} is the average concentration reading of the measurements at voltage V_1, in nmol/mol;
- C_{V2} is the average concentration reading of the measurements at voltage V_2, in nmol/mol;
- V_1 is the minimum voltage V_{min} in V specified by the manufacturer;
- V_2 is the maximum voltage V_{max} in V specified by the manufacturer

For reporting the dependence on voltage, the higher value of the result at zero and span level shall be taken.

b_v shall meet the performance criterion specified above.

7.3 Testing

For the purpose of testing the voltage sensitivity coefficient, a transformer was interposed between the analyser and the voltage supply. Sample gas was fed at various voltages at zero and reference point.

7.4 Evaluation

The following sensitivity coefficients to electrical voltage resulted from the tests:

Table 20: Sensitivity coefficient to electrical voltage at zero point and at reference point

	Requirement	Device 1		Device 2	
Sensitivity coeff. of voltage b_v at zero level [nmol/mol/V]	≤ 0.3	0.01	✓	0.01	✓
Sensitivity coeff. of voltage b_v at span level [nmol/mol/V]	≤ 0.3	0.01	✓	0.02	✓

7.5 Assessment

The sensitivity coefficient of electrical voltage b_v does not exceed the performance criteria of max. 0.3 nmol/mol/V stipulated in Standard DIN EN 14625 at any point. For both systems, the highest value b_v is used for the purpose of calculating uncertainty. For system 1 it is 0.01 nmol/mol/V and for system 2 it is 0.02 nmol/mol/V.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Table 21: Individual results for the tests of the sensitivity coefficient to electrical voltage

Time	Voltage [V]	Concentration	Device 1 [nmol/mol]	Device 2 [nmol/mol]
12:58:00	198	0	0.31	0.16
12:59:00	198	0	0.31	0.31
13:00:00	198	0	-1.09	-0.16
Average C_{V1} at zero			-0.16	0.10
13:05:00	264	0	0.31	0.63
13:06:00	264	0	0.31	1.25
13:07:00	264	0	0.47	1.25
Average C_{V2} at zero			0.36	1.04
13:17:00	198	200.00	197.66	195.31
13:18:00	198	200.00	197.97	197.03
13:19:00	198	200.00	198.28	197.34
Average C_{V1} at span			197.97	196.56
13:24:00	264	200.00	197.34	195.47
13:25:00	264	200.00	197.19	195.16
13:26:00	264	200.00	196.72	194.89
Average C_{V2} at span			197.08	195.17

7.1 8.4.11 Interferents

Interferents at zero and at an ozone concentration c_t (at the level of the hourly limit value = 120 nmol/mol for ozone). The highest permissible response to the interfering components toluene and m-Xylene shall not exceed 5.0 nmol/mol (i.e. 10 µg/m³) respectively.

7.2 Test procedure

The analyser response to certain interferents, which are to be expected to be present in ambient air, shall be tested. The interferents can give a positive or negative response. The test shall be performed at zero and at a test concentration (c_t) similar to the hourly alert threshold value (120 nmol/mol for ozone).

The concentration of the mixtures of the test gases with the interferent shall have an expanded uncertainty of ≤ 5 % and shall be traceable to nationally accepted standards. The interferents to be tested and their respective concentrations are given in Table 22. The influence of each interferent shall be determined separately. A correction factor on the concentration of the measurand shall be made for the dilution effect due to addition of an interferent (e.g. water vapour).

After adjustment of the analyser at zero and span level, the analyser shall be fed with a mixture of zero gas and the interferent to be investigated with the concentration given in Table 22. With this mixture, one independent measurement followed by two individual measurements shall be carried out. This procedure shall be repeated with a mixture of the measurand at concentration c_t and the interferent to be investigated. The influence quantity at zero and concentration c_t is calculated from:

$$X_{\text{int},z} = x_z$$

$$X_{\text{int},ct} = x_{ct} - c_t$$

where

$X_{\text{int},z}$ is the die influence quantity of the interferent at zero, in nmol/mol;

x_z is the average of the measurements at zero, in nmol/mol;

$X_{\text{int},ct}$ is the influence quantity of the interferent at concentration c_t, in nmol/mol;

x_{ct} is the average of the measurements at concentration c_t, in nmol/mol;

c_t is the concentration of the gas applied at a level of the hourly limit, in nmol/mol.

The response to interferents shall comply with the performance criteria stated above at zero level as well as at concentration c_t.

7.3 Testing

The test was performed in accordance with the requirements on testing as stipulated in DIN EN 14625. The systems were adjusted to zero concentration and to the concentration c_t (approx. 120 nmol/mol). Zero and test gas with various interferents were then applied. Interferents and their respective concentrations used during testing are provided in Table 22.

Table 22: Interferents according to DIN EN 14625

Interferent	Concentration
H_2O	19 mmol/mol
Toluene	0.5 µmol/mol
m-Xylene	0.5 µmol/mol

7.4 Evaluation

The following table lists the response levels of individual interferents.

Table 23: Influence of the interferents tested (c_t = 120 nmol/mol)

	Requirement	**Device 1**		**Device 2**	
Influence quantity interferent H_2O at zero [nmol/mol/V]	≤ 10.0 nmol/mol	2.70	✓	-0.01	✓
Influence quantity interferent H_2O at c_t [nmol/mol/V]	≤ 10.0 nmol/mol	-0.67	✓	0.72	✓
Influence quantity interferent toluol at zero [nmol/mol/V]	≤ 5.0 nmol/mol	1.88	✓	2.02	✓
Influence quantity interferent toluol at c_t [nmol/mol/V]	≤ 5.0 nmol/mol	0.38	✓	0.82	✓
Influence quantity interferent m-Xylol at zero [nmol/mol/V]	≤ 5.0 nmol/mol	2.51	✓	2.68	✓
Influence quantity interferent m-Xylol at c_t [nmol/mol/V]	≤ 5.0 nmol/mol	4.53	✓	3.86	✓

7.5 Assessment

Cross-sensitivity at zero point is 2.70 nmol/mol for system 1 and -001 nmol/mol for system 2 for the component H_2O; 1.88 nmol/mol for system 1 and 2.02 nmol/mol for system 2 for toluene; 2.51 nmol/mol for system 1 and 2.68 nmol/mol for system 2 for m-Xylene.

Cross-sensitivity at the limit value c_t is -0.67 nmol/mol for system 1 and 0.72 nmol/mol for system 2 for H_2O; 0.38 nmol/mol for system 1 and -0.82 nmol/mol for system 2 for toluene; 4.53 nmol/mol for system 1 and 3.86 nmol/mol for system 2 for m-Xylene.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Table 24 provides the individual readings obtained from the test.

Table 24: Individual responses to interferents

Date and interferent	Time without interferent	Time with interferent	Device 1 [nmol/mol]		Device 2 [nmol/mol]	
			Without int.	With int.	Without int.	With int.
	07:47:40	09:02:50	0.31	2.03	-0.53	-0.89
Zero + H_2O (19 mmol/mol)	07:51:20	09:06:30	-0.02	2.59	-1.80	-0.55
	07:55:00	09:12:00	-0.20	3.59	-0.82	-1.75
	Average x_z		**0.03**	**2.74**	**-1.05**	**-1.06**
	12:36:20	14:26:20	127.10	125.63	122.32	122.60
Span ct + H2O (19 mmol/mol)	12:42:45	14:26:20	126.30	125.63	121.86	122.60
	12:46:25	14:36:25	125.95	126.09	121.66	122.79
	Average x_{ct}		**126.45**	**125.78**	**121.95**	**122.66**
	07:47:40	08:06:00	0.31	2.52	-0.53	1.10
Zero + Toluol (0,5 µmol/mol)	07:51:20	08:10:35	-0.02	1.71	-1.80	0.78
	07:55:00	08:19:45	-0.20	1.51	-0.82	1.04
	Average x_z		**0.03**	**1.91**	**-1.05**	**0.97**
	10:05:10	10:27:10	122.61	123.96	118.23	119.48
Span c_t + Toluol (0,5 µmol/mol)	10:09:45	10:30:50	122.72	123.03	119.56	120.36
	10:17:05	10:35:25	123.70	123.17	120.19	120.59
	Average x_{ct}		**123.01**	**123.39**	**119.33**	**120.14**
	15:29:35	16:22:45	-0.35	3.35	1.05	5.32
Zero + m-Xylol (0,5 µmol/mol)	15:33:15	16:41:05	-0.65	1.47	0.70	2.77
	15:42:25	16:47:30	0.54	2.24	0.00	1.69
	Average x_z		**-0.15**	**2.35**	**0.59**	**3.26**
	10:05:10	11:07:30	122.61	127.61	118.23	123.33
Span c_t + m-Xylol (0,5 µmol/mol)	10:09:45	11:14:50	122.72	127.46	119.56	124.39
	10:17:05	11:19:25	123.70	127.55	120.19	121.83
	Average x_{ct}		**123.01**	**127.54**	**119.33**	**123.18**

7.1 8.4.12 Averaging test

The averaging effect shall not exceed 7 % of the instrument reading.

7.2 Test procedure

The averaging test gives a measure of the uncertainty in the averaged values caused by short-term concentration variations in the sampled air shorter than the time scale of the measurement process in the analyser. In general, the output of an analyser is a result of the determination of a reference concentration (normally zero) and the actual concentration which takes a certain time.

For the determination of the uncertainty due to the averaging, the following concentrations are applied to the analyser and readings are taken at each concentration: a constant ozone concentration between zero and concentration c_t.

The time period (t_c) of the constant ozone concentration shall be at least equal to the period necessary to obtain four independent readings (which is equal to at least 16 response times). The time period (t_v) of the varying ozone concentration shall be at least equal to a period to obtain four independent readings. The time period (t_{O3}) for the ozone concentration shall be 45 s followed by a period (t_{zero}) of 45 s of zero concentration.

Further:

c_t is the test gas concentration, in nmol/mol;

t_v is a time period including a whole number of t_{O3} and t_{zero} pairs, and contains a minimum of three such pairs, in s.

The change from t_{O3} to t_{zero} shall be within 0.5 s. The change from t_c to t_v shall be within one response time of the analyser under test.

The averaging effect (E_{av}) is calculated according to:

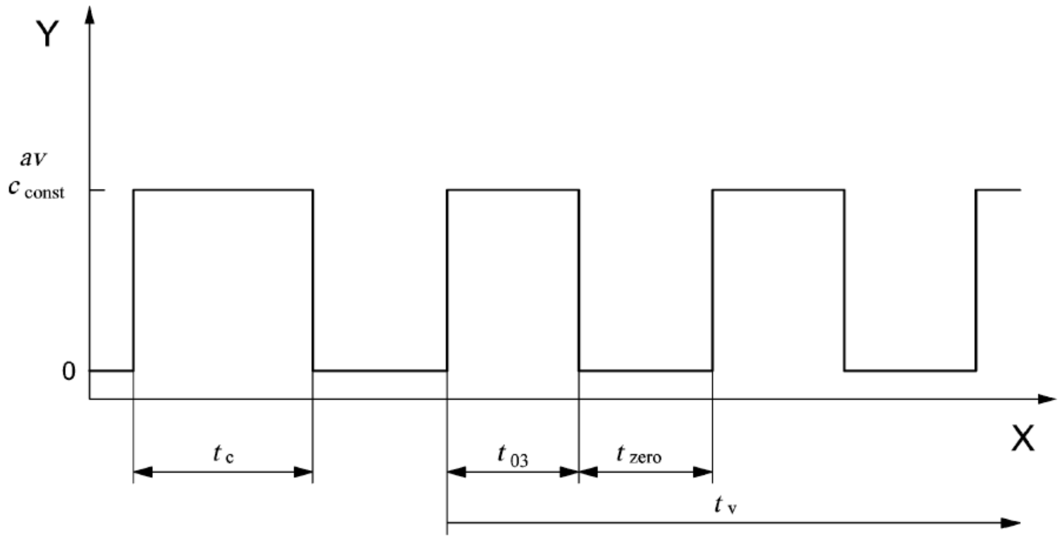
$$E_{av} = \frac{C_{const}^{av} - 2C_{\mathrm{var}}^{av}}{C_{const}^{av}} * 100$$

where

E_{av} is the averaging effect, in (%)

C_{const}^{av} is the average of at least four independent measurements during the constant concentration period (t_c), in nmol/mol;

C_{var}^{av} is the average of the at least four independent measurements during the variable concentration period (t_v), in nmol/mol.



Key

Y concentration (nmol/mol)

X time

Figure 11: Concentration variation for the averaging test (t_{O3} = t_{zero} = 45 s.)

7.3 Testing

The averaging test was performed in accordance with the requirements on testing as stipulated in DIN EN 14625. As the measuring system under test measures ozone directly, the test was performed with stepwise varied ozone concentrations between zero and concentration c_t (120 nmol/mol). First, the average was calculated at a constant concentration of test gas. Then, an alternating change between zero and test gas every 45 s was established using a three-way valve. For the period of alternating test gas application, the average was calculated as well.

7.4 Evaluation

The following averages were obtained during testing:

Table 25: Results from the averaging test

	Requirement	Device 1		Device 2	
Averaging effect E_{av} [%]	≤ 7%	-1.57	✓	-0.54	✓

This results in the following averaging effects:

System 1 (001): -1.57 %

System 2 (002): -0.54 %

7.5 Assessment

This is in complete compliance with the performance criteria stipulated DIN EN 14625.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Table 26 provides the individual results for the averaging test.

Table 26: Individual results of the averaging test

	Time	Device 1 [nmol/mol]	Device 2 [nmol/mol]
Average constant concentration $C_{av,c}$	10:42:00 till 11:03:00	120.0	118.1
Average variable concentration $C_{av,v}$	11:03:00 till 11:26:00	59.0	57.2

	Time	Device 1 [nmol/mol]	Device 2 [nmol/mol]
Average constant concentration $C_{av,c}$	12:01:00 till 12:22:00	124.6	121.1
Average variable concentration $C_{av,v}$	12:22:00 till 12:45:00	65.5	64.7

	Time	Device 1 [nmol/mol]	Device 2 [nmol/mol]
Average constant concentration $C_{av,c}$	12:45:00 till 13:52:00	125.9	122.8
Average variable concentration $C_{av,v}$	13:52:00 till 14:15:00	63.6	60.1

7.1 8.4.13 Difference sample/calibration port

The difference between sample and calibration port shall not exceed 1.0 %.

7.2 Test procedure

If the analyser has different ports for feeding sample gas and calibration gas, the difference in response of the analyser to feeding through the sample or calibration port shall be tested. The test shall be carried out by feeding the analyser with a test gas with a concentration of 70 % to 80 % of the maximum of the certification range of ozone through the sample port. The test shall consist of one independent measurement followed by two individual measurements. After a period of at least four response times, the test shall be repeated using the calibration port. The difference shall be calculated according to:

$$\Delta_{SC} = \frac{x_{sam} - x_{cal}}{c_t} \times 100$$

where

Δ_{SC} is the difference sample/calibration port, in %;

x_{sam} is the average of the measured concentration using the sample port, in nmol/mol;

x_{cal} is the average of the measured concentration using the calibration port, in nmol/mol;

c_t is the concentration of the test gas, in nmol/mol.

Δ_{SC} shall comply with the performance criterion specified above.

7.3 Testing

The test was performed in accordance with the requirements on testing as stipulated in DIN EN 14625. For test gas feeding the path was controlled by means of a three-way valve between sample and calibration port.

7.4 Evaluation

The following differences between sample and calibration ports were determined:

System 1 (001): -0,37 %
System 2 (002): 0,22 %

7.5 Assessment

This is in complete compliance with the performance criteria stipulated in Standard DIN EN 14625.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Individual results are provided in Table *27*.

Table 27: Individual results for the difference between sample and calibration port

Time	Device 1 [nmol/mol]	Device 2 [nmol/mol]
Test gas to the sample port		
12:01	186.4	188.3
12:03	187.0	188.4
12:05	187.3	188.9
Average	**186.9**	**188.5**
Test gas to the calibration port		
12:36	187.8	188.2
12:38	188.2	188.4
12:40	186.9	187.7
Average	**187.6**	**188.1**
Deviation [%]	**-0.37**	**0.22**

7.1 8.4.14 Residence time in the analyser

The residence time in the analyser shall not exceed 3.0 s.

7.2 Test procedure

The residence time inside the analyser shall be calculated on the basis of the flow and volumes of the tubing and other relevant components inside the analyser.

7.3 Testing

From sample inlet to the measuring cell, the gas volume of the Serinus 10 analyser is 4.75 ml. The nominal sample gas volume is 0.5 l/min. This results in a residence time inside the analyser of 0.6 s.

7.4 Evaluation

Not applicable in this instance.

7.5 Assessment

The residence time inside the analyser 0.6 s.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Not applicable in this instance.

7.1 8.5.4 Long-term drift

The long-term drift at zero shall not exceed 5.0 nmol/mol (i.e. 10.0 µg/m³).
The long-term drift at span level shall not exceed 5 % of the certification range (i.e. 12.5 nmol/mol in a measuring range of 0 to 250 nmol/mol).

7.2 Test procedure

After each bi-weekly zero and span check, the drift of the analysers under test shall be calculated at zero and span following the procedures as given underneath. If the drift compared to the initial calibration exceeds one of the performance criteria for drift at zero or span level, the "period of unattended operation" equals the number of weeks until the observation of the infringement, minus two weeks. For further (uncertainty) calculations, the values for "long term drift" are the values for zero and span drift over the period of unattended operation.

At the beginning of the drift period, five individual measurements are recorded (after waiting the time equivalent to one independent measurement just after the calibration) at zero and at span level.

The long-term drift is calculated as follows:

$$D_{L,Z} = (C_{Z,1} - C_{Z,0})$$

where

$D_{L,Z}$ is the drift at zero, in nmol/mol;

$C_{Z,0}$ is the average concentration of the measurements at zero at the beginning of the drift period (just after the initial calibration), in nmol/mol;

$C_{Z,1}$ is the average concentration of the measurements at zero at the end of the drift period, in nmol/mol.

$D_{L,Z}$ shall comply with the performance criterion specified above.

$$D_{L,S} = \frac{(C_{S,1} - C_{S,0}) - D_{L,Z}}{C_{S,1}} \times 100$$

where

$D_{L,S}$ is the drift at span concentration c_t, in %;

$C_{S,0}$ is the average concentration of the measurements at span level at the beginning of the drift period just after the initial calibration, in nmol/mol;

$C_{S,1}$ is the average concentration of the measurements at span level at the end of the drift period, in nmol/mol.

$D_{L,S}$ shall comply with the performance criterion specified above.

7.3 Testing

For the purpose of the test, test gas was applied bi-weekly. Table 28 and Table 29 list the results of this bi-weekly test gas application.

7.4 Evaluation

Table 28: Results for the long term drift at zero for the component ozone

		Device 1 [nmol/mol]	Device 2 [nmol/mol]
$C_{Z,0}$	03.07.2013	-1.20	-0.22
$C_{Z,1}$	22.07.2013	-1.1	0.2
$D_{L,Z}$	**22.07.2013**	**0.10**	**0.42**
$C_{Z,1}$	01.08.2013	-3	-0.75
$D_{L,Z}$	**01.08.2013**	**-1.80**	**-0.53**
$C_{Z,1}$	16.08.2013	0.61	0.02
$D_{L,Z}$	**16.08.2013**	**1.81**	**0.24**
$C_{Z,1}$	02.09.2013	-1.82	-0.34
$D_{L,Z}$	**02.09.2013**	**-0.62**	**-0.12**
$C_{Z,1}$	16.09.2013	-1.77	-0.63
$D_{L,Z}$	**16.09.2013**	**-0.57**	**-0.41**
$C_{Z,1}$	30.09.2013	-1.62	-1.59
$D_{L,Z}$	**30.09.2013**	**-0.42**	**-1.37**
$C_{Z,1}$	04.10.2013	-2.38	-1.69
$D_{L,Z}$	**04.10.2013**	**-1.18**	**-1.47**

Table 29: Results for the long term drift at span point for the component ozone

		Device 1 [nmol/mol]	Device 2 [nmol/mol]
$C_{S,0}$	03.07.2013	186.3	185.8
$C_{S,1}$	22.07.2013	182.2	181.7
$D_{L,S}$	**22.07.2013**	**-2.25%**	**-2.44%**
$C_{S,1}$	01.08.2013	184.7	184.0
$D_{L,S}$	**01.08.2013**	**0.11%**	**-0.67%**
$C_{S,1}$	16.08.2013	186.9	188.4
$D_{L,S}$	**16.08.2013**	**-0.63%**	**1.25%**
$C_{S,1}$	02.09.2013	188.7	188.1
$D_{L,S}$	**02.09.2013**	**1.63%**	**1.29%**
$C_{S,1}$	16.09.2013	186.7	186.2
$D_{L,S}$	**16.09.2013**	**0.50%**	**0.43%**
$C_{S,1}$	30.09.2013	188.2	188.2
$D_{L,S}$	**30.09.2013**	**1.22%**	**1.99%**
$C_{S,1}$	04.10.2013	187.6	188.2
$D_{L,S}$	**04.10.2013**	**1.32%**	**2.05%**

7.5 Assessment

The maximum long term drift at zero $D_{l,z}$ is 1.81 nmol/mol for system 1 and -1.47 nmol/mol for system 2. The maximum long term drift at span point $D_{l,s}$ is -2.25 % for system 1 and -2.44 % for system 2.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

The individual results of the determination of long term drift behaviour are provided in Table 30.

Table 30: Individual results for the long term drift

Date	Time	Device 1	Device 2	Time	Device 1	Device 2
	Zero			Span		
	[hh:mm]	[nmol/mol]	[nmol/mol]	[hh:mm]	[nmol/mol]	[nmol/mol]
03/07/2013	07:55	-1.3	-0.4	08:50	186.3	185.6
03/07/2013	07:56	-1.5	-0.5	08:51	185.9	185.5
03/07/2013	07:57	-1.3	0	08:52	185.6	185.7
03/07/2013	07:58	-1	-0.4	08:53	186.6	186.1
03/07/2013	07:59	-0.9	0.2	08:56	187.1	186.2
Average		**-1.20**	**-0.22**		**186.3**	**185.8**
22/07/2013	17:18	-1.1	0.2	17:51	182.2	181.7
01/08/2013	15:07	-3	-0.75	15:58	184.7	184.0
16/08/2013	08:33	0.61	0.02	09:30	186.9	188.4
02/09/2013	10:26	-1.82	-0.34	12:20	188.7	188.1
16/09/2013	08:46	-1.77	-0.63	13:06	186.7	186.2
30/09/2013	11:04	-1.62	-1.59	11:57	188.2	188.2
04/10/2013	09:32	-2.38	-1.69	10:37	187.6	188.2

The above listed values are averages of one independent measurement and four individual measurements.

7.1 8.5.5 Reproducibility standard deviation for ozone under field conditions

The reproducibility standard deviation under field conditions shall not exceed 5 % of the average over a period of 3 months.

7.2 Test procedure

The reproducibility standard deviation for ozone under field conditions is calculated from the measured hourly averaged data during the three-month period.

The difference $\Delta x_{f,i}$ for each *i*th parallel measurement is calculated from:

$$\Delta x_{f,i} = x_{f,1,i} - x_{f,2,i}$$

where

$\Delta x_{f,i}$ is the *i*th difference in a parallel measurement, in nmol/mol;

$x_{f,1,i}$ is the *i*th measurement result of analyser 1, in nmol/mol;

$x_{f,2,i}$ is the *i*th measurement result of analyser 2, in nmol/mol.

The reproducibility standard deviation under field conditions ($s_{r,f}$) is calculated according to:

$$s_{r,f} = \frac{\left(\sqrt{\frac{\sum_{i=1}^{n} \Delta x_{f,i}^2}{2 * n}}\right)}{c_f} \times 100$$

where

$s_{r,f}$ is the reproducibility standard deviation under field conditions, in %;

n is the number of parallel measurements;

c_f is the average concentration of ozone measured during the field test, in nmol/mol.

The reproducibility standard deviation under field conditions, $s_{r,f}$, shall comply with the performance criterion specified above.

7.3 Testing

Using the equations given above, the reproducibility standard deviation under field conditions was calculated from the data averaged hourly during the field test.

In order to demonstrate that the measuring system operates reliably at higher concentrations as well, the sample air was enriched with ozone from time to time.

7.4 Evaluation

Table 31: Determination of the reproducibility standard deviation on the basis of all data collected during the field test

Reproducibility standard deviation in the field test				
Number of measurements	n	=	2233	
Average of both analysers		=	62.59	nmol/mol
Standard deviation from paired measurements	sd	=	1.22	nmol/mol
Reproducibility standard deviation (%)	**Sr,f**	**=**	**1.95**	**%**

The reproducibility standard deviation under field conditions is 1.95 % of the average.

7.5 Assessment

The reproducibility standard deviation for ozone was 1.95 % of the average over a period of 3 months in the field. Thus, the requirements of Standard DIN EN 14625 are met.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Figure 12 illustrates the reproducibility standard deviation under field conditions.

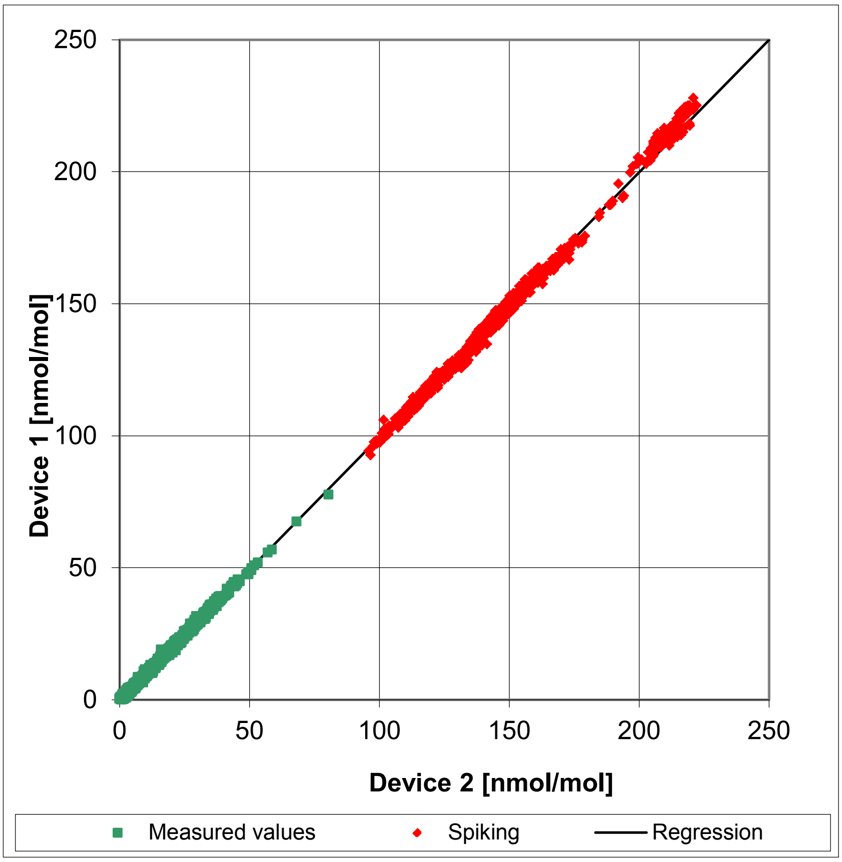


Figure 12: Illustration of the reproducibility standard deviation under field conditions

7.1 8.5.6 Period of unattended operation

The maintenance interval shall be at least 2 weeks.

7.2 Equipment

Not required for this criterion.

7.3 Testing

For this criterion, the tasks necessary to ensure proper functioning of the measuring system as well as the corresponding interval were identified. In determining the maintenance interval, the results of the drift tests at zero and span point according to 7.1 8.5.4 Long-term drift were taken into consideration.

7.4 Evaluation

No excessive drift behaviour was observed during the entire period of the field test. The maintenance interval is therefore subject to the necessary maintenance tasks.

During operation, maintenance tasks may primarily be limited to contamination and plausibility checks as well as potential status signals and error warnings.

7.5 Assessment

The maintenance interval is subject to the necessary maintenance tasks and is 4 weeks.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Not applicable in this instance.

7.1 8.5.7 Period of availability of the analyser

The availability of the analyser shall be at least 90 %.

7.2 Test procedure

The correct operation of the analysers shall be checked at least every 14 days. It is recommended to perform this check every day during the first 14 days. These checks consist of plausibility checks on the measured values, as well as, when available, on status signals and other relevant parameters. Time, duration and nature of any malfunctioning shall be logged.

The total time period with useable measuring data is the period during the field test during which valid measuring data of the ambient air concentrations are obtained. In this time period, the time needed for calibrations, conditioning of sample systems and filters and maintenance shall not be included.

The availability of the analyser is calculated as:

$$A_a = \frac{t_u}{t_t} * 100$$

where

A_a is the availability of the analyser, in %;

t_u is the total time period with validated measuring data;

t_t is the time period of the field test minus the time for calibration, conditioning and maintenance

t_u and t_t shall be expressed in the same units.

The availability of each analyser shall comply with the criterion specified above.

7.3 Testing

Using the equation given above, availability was calculated on the basis of the overall time of the field test and the down times which occurred during this period.

7.4 Evaluation

The down times during the field are listed in Table 32.

Table 32: Availability of the Serinus 10 measuring system

		System 1	System 2
Time in the field	h	2248	2248
Down time	h	0	0
Maintenance	h	15	15
Total operating time	h	2233	2233
Total operating time incl. maintenance	h	2248	2248
Availability	%	100	100

Maintenance times result from the daily test gas feeding for the purpose of determining the drift behaviour and the maintenance interval as well as times required to change the internal Teflon filters in the sample gas line.

7.5 Assessment

The availability is 100 %. This complies with the requirements of Standard DIN EN 14625.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Not applicable in this instance.

7.1 8.6 Total uncertainty in accordance with Annex E of DIN EN 14625 (2012)

The type approval of the analyser consists of the following steps:

***1)** The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table E.1 of DIN EN 14625.*

***2)** The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory tests shall fulfil the criterion as stated in Annex I of Directive 2008/50/EC (15 % for fixed measurements or 25 % for indicative measurements). This criterion is the maximum uncertainty of hourly values of continuous measurements at the hourly limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of DIN EN 14625.*

***3)** The value of each of the individual performance characteristics tested in the field shall fulfil the criterion stated in Table E.1 of DIN EN 14625.*

***4)** The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory and field tests shall fulfil the criterion as stated in Annex I of Directive 2008/50/EC (15 % for fixed measurements or 25 % for indicative measurements). This criterion is the maximum uncertainty of hourly values of continuous measurements at the hourly limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of DIN EN 14625.*

7.2 Equipment

Calculation of total uncertainty in accordance with Annex E of Standard DIN EN 14625 (2012).

7.3 Testing

At the end of the tests for type approval, total uncertainty was calculated using the values obtained during testing.

7.4 Evaluation

1) The value of each individual performance characteristic tested in the laboratory fulfils the criterion stated in Table E.1 of DIN EN 14625.
2) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory test fulfils the criterion.
3) The value of each of the individual performance characteristics tested in the field fulfils the criterion stated in Table E.1 of DIN EN 14625.
4) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory and field tests fulfils the criterion.

7.5 Assessment

The total uncertainty of the measuring system complies with the performance criteria.

Does this comply with the performance criterion? yes

7.6 Detailed presentation of test results

Table 33 summarises the results for items 1 and 3.

Table 34 and Table 36 provide the results for item 2.

Table 35 and Table 37 list the results for item 4.

Table 33: Performance criteria according to DIN EN 14625

Performance characteristic	Criterion	Test result	Compliance	Page
8.4.5 Repeatability standard deviation at zero	≤ 1.0 nmol/mol	S_r System 1: 0.32 nmol/mol S_r System 2: 0.60 nmol/mol	yes	78
8.4.5 Repeatability standard deviation at the concentration c_t	≤ 3.0 nmol/mol	S_r System 1: 0.16 nmol/mol S_r System 2: 0.40 nmol/mol	yes	78
8.4.6 "lack of fit" (deviation from the linear regression)	Largest deviation from the linear regression line at concentrations above zero ≤ 4.0 % of the reading Deviation at zero ≤ 5 nmol/mol	$X_{l.z}$ System 1: NP 1.25 nmol/mol X_l System 1: RP 1.38 % $X_{l.z}$ System 2: NP 1.50 nmol/mol X_l System 2: RP 1.16 %	yes	81
8.4.7 Sensitivity coefficient to sample gas pressure	≤ 2.0 nmol/mol/kPa	b_{gp} System 1: 0.06 nmol/mol/kPa b_{gp} System 2: 0.04 nmol/mol/kPa	yes	86
8.4.8 Sensitivity coefficient to sample gas temperature	≤ 1.0 nmol/mol/K	b_{gt} System 1: 0.13 nmol/mol/K b_{gt} System 2: 0.14 nmol/mol/K	yes	88
8.4.9 Sensitivity coefficient to surrounding temperature	≤ 1.0 nmol/mol/K	b_{st} System 1: 0.421 nmol/mol/K b_{st} System 2: 0.206 nmol/mol/K	yes	90
8.4.10 Sensitivity coefficient to electric voltage	≤ 0.3 nmol/mol/V	b_v System 1: RP 0.01 nmol/mol/V b_v System 2: RP 0.02 nmol/mol/V	yes	93
8.4.11 Interferents at zero and concentration c_t	H_2O ≤ 10.0 nmol/mol toluene ≤ 5.0 nmol/mol m-Xylene ≤ 5.0 nmol/mol	H_2O System 1: NP 2.7 nmol/mol / RP -0.67 nmol/mol System 2: NP -0.01 nmol/mol / RP 0.72 nmol/mol Toluene System 1: NP 1.88 nmol/mol / RP 0.38 nmol/mol System 2: NP 2.02 nmol/mol / RP 0.82 nmol/mol m-Xylene System 1: NP 2.51 nmol/mol / RP 4.53 nmol/mol System 2: NP 2.86 nmol/mol / RP 3.86 nmol/mol	yes	95

Performance characteristic	Criterion	Test Result	Com-pliance	Page
8.4.12 Averaging effect	≤ 7.0 % of the measured value	E_{av} System 1: -1.57 % E_{av} System 2: -0.54 %	yes	95
8.4.13 Difference sample/calibration port	≤ 1.0 %	Δ_{SC} System 1: -0.37 % Δ_{SC} System 2: 0.22 %	yes	101
8.4.3 Response time (rise)	≤ 180 s	t_r System 1: 44 s t_r System 2: 43 s	yes	70
8.4.3 Response time (fall)	≤ 180 s	t_f System 1: 53 s t_f System 2: 51 s	yes	70
8.4.3 Difference between rise and fall	≤ 10 s	t_d System 1: -9 s t_d System 2: -7 s	yes	70
8.4.14 Residence in the analyser	≤ 3.0 s	System 1: 0.6 s System 2: 0.6 s	yes	103
8.5.6 Period of unattended operation	3 months or less if specified by the manufacturer, no less than 2 weeks	System 1: 4 weeks System 2: 4 weeks	yes	111
8.5.7 Availability of the analyser	> 90 %	A_a System 1: 100 % A_a System 2: 100 %	yes	112
8.5.5 Reproducibility standard deviation under field conditions	≤ 5.0 % of the average over a period of 3 months	$S_{r,f}$ System 1: 1.95 % $S_{r,f}$ System 2: 1.95 %	yes	108
8.5.4 Long-term drift at zero	≤ 5.0 nmol/mol	$C_{,z}$ System 1: 1.81 nmol/mol $C_{,z}$ System 2: 1.47 nmol/mol	yes	104
8.5.4 Long-term drift at span level	≤ 5.0 % of the maximum of the certification range	$C_{,s}$ System 1: max. -2.25 % $C_{,s}$ System 2: max. -2.44 %	yes	104
8.4.4 Short-term drift at zero	≤ 2.0 nmol/mol over a period of 12 h	$D_{s,z}$ System 1: 0.49 nmol/mol $D_{s,z}$ System 2: -1.04 nmol/mol	yes	74
8.4.4 Short-term drift at span level	≤ 6.0 nmol/mol over a period of 12 h	$D_{s,s}$ System 1: 1.89 nmol/mol $D_{s,s}$ System 2: 1.91 nmol/mol	yes	74

Table 34: Expanded uncertainty from the results of the laboratory test for system 1

Measuring device:	Ecotech Serinus 10	Serial-No.:	13-0091 (Device 1)	
Measured component:	O3	1h-alert threshold:	120	nmol/mol

No.	Performance characteristic		Performance criterion	Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.320	$u_{r,z}$	0.07	0.0055	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	0.160	$u_{r,lh}$	0.04	0.0014	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.380	$u_{l,lh}$	0.96	0.9141	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.060	u_{gp}	0.62	0.3811	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.130	u_{gt}	1.49	2.2089	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.421	u_{st}	3.15	9.9431	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.010	u_V	0.12	0.0152	
8a	Interferent H_20 with 21 mmol/mol	≤	10 nmol/mol (Zero)	2.700	u_{H2O}	-0.40	0.1595	
		≤	10 nmol/mol (Span)	-0.670				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	1.880	$u_{int,pos}$	2.83	8.0082	
		≤	5.0 nmol/mol (Span)	0.380	or			
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	2.510				
		≤	5.0 nmol/mol (Span)	4.530	$u_{int,neg}$			
9	Averaging effect	≤	7.0% of measured value	-1.570	u_{av}	-1.09	1.1832	
18	Difference sample/calibration port	≤	1.0%	-0.370	$u_{\Delta sc}$	-0.44	0.1971	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.20	1.4400	
				Combined standard uncertainty	u_c		4.9454	nmol/mol
				Expanded uncertainty	U		9.8909	nmol/mol
				Relative expanded uncertainty	W		8.24	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 35: Expanded uncertainty from the results of the laboratory and field tests for system 1

Measuring device:	Ecotech Serinus 10	Serial-No.:	13-0091 (Device 1)	
Measured component:	O3	1h-alert threshold:	120	nmol/mol

No.	Performance characteristic		Performance criterion	Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.320	$u_{r,z}$	0.07	0.0055	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	0.160	$u_{r,lh}$	not considered, as ur,lh = 0,03 < ur,f	-	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.380	$u_{l,lh}$	0.96	0.9141	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.060	u_{gp}	0.62	0.3811	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.130	u_{gt}	1.49	2.2089	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.421	u_{st}	3.15	9.9431	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.010	u_V	0.12	0.0152	
8a	Interferent H_20 with 21 mmol/mol	≤	10 nmol/mol (Zero)	2.700	u_{H2O}	-0.40	0.1595	
		≤	10 nmol/mol (Span)	-0.670				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	1.880	$u_{int,pos}$	2.83	8.0082	
		≤	5.0 nmol/mol (Span)	0.380	or			
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	2.510				
		≤	5.0 nmol/mol (Span)	4.530	$u_{int,neg}$			
9	Averaging effect	≤	7.0% of measured value	-1.570	u_{av}	-1.09	1.1832	
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	1.950	$u_{r,f}$	2.34	5.4756	
11	Long term drift at zero level	≤	5.0 nmol/mol	1.810	$u_{d,l,z}$	1.05	1.0920	
12	Long term drift at span level	≤	5.0% of max. of certification range	-2.250	$u_{d,l,lh}$	-1.56	2.4300	
18	Difference sample/calibration port	≤	1.0%	-0.370	$u_{\Delta sc}$	-0.44	0.1971	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.20	1.4400	
				Combined standard uncertainty	u_c		5.7839	nmol/mol
				Expanded uncertainty	U		11.5678	nmol/mol
				Relative expanded uncertainty	W		9.64	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 36: Expanded uncertainty from the results of the laboratory test for system 2

Measuring device:	Ecotech Serinus 10				Serial-No.:		13-0090 (Device 2)	
Measured component:	O3				1h-alert threshold:		120	nmol/mol
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.600	$u_{r,Z}$	0.14	0.0188	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	0.400	$u_{r,lv}$	0.09	0.0086	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.160	$u_{l,lv}$	0.80	0.6459	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.040	u_{gp}	0.41	0.1694	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.140	u_{gt}	1.61	2.5931	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.206	u_{st}	1.59	2.5147	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.020	u_V	0.25	0.0606	
8a	Interferent H_20 with 21 mmol/mol	≤	10 nmol/mol (Zero)	-0.010	u_{H2O}	0.53	0.2791	
		≤	10 nmol/mol (Span)	0.720				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	2.020	$u_{int,pos}$			
		≤	5.0 nmol/mol (Span)	0.820	or	2.70	7.3008	
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	2.680				
		≤	5.0 nmol/mol (Span)	3.860	$u_{int, neg}$			
9	Averaging effect	≤	7.0% of measured value	-0.540	u_{av}	-0.37	0.1400	
18	Difference sample/calibration port	≤	1.0%	0.220	u_{Dsc}	0.26	0.0697	
21	Uncertainty of test gas	≤	3.0%	2.000	ucg	1.20	1.4400	
					Combined standard uncertainty	u_c	3.9039	nmol/mol
					Expanded uncertainty	U	7.8079	nmol/mol
					Relative expanded uncertainty	W	6.51	%
					Maximum allowed expanded uncertainty	W_{req}	15	%

Table 37: Expanded uncertainty from the results of the laboratory and field tests for system 2

Measuring device:	Ecotech Serinus 10				Serial-No.:		13-0090 (Device 2)	
Measured component:	O3				1h-alert threshold:		120	nmol/mol
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.600	$u_{r,z}$	0.14	0.0188	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	0.400	$u_{r,lh}$	not considered, as ur,lh = 0,09 < ur,f	-	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.160	$u_{l,lh}$	0.80	0.6459	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.040	u_{gp}	0.41	0.1694	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.140	u_{gt}	1.61	2.5931	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.206	u_{st}	1.59	2.5147	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.020	u_V	0.25	0.0606	
8a	Interferent H_20 with 21 mmol/mol	≤	10 nmol/mol (Zero)	-0.010	u_{H2O}	0.53	0.2791	
		≤	10 nmol/mol (Span)	0.720				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	2.020	$u_{int,pos}$			
		≤	5.0 nmol/mol (Span)	0.820	or	2.70	7.3008	
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	2.680				
		≤	5.0 nmol/mol (Span)	3.860	$u_{int, neg}$			
9	Averaging effect	≤	7.0% of measured value	-0.540	u_{av}	-0.37	0.1400	
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	1.950	$u_{r,f}$	2.34	5.4756	
11	Long term drift at zero level	≤	5.0 nmol/mol	1.470	$u_{d,l,z}$	0.85	0.7203	
12	Long term drift at span level	≤	5.0% of max. of certification range	-2.440	$u_{d,l,lh}$	-1.69	2.8577	
18	Difference sample/calibration port	≤	1.0%	0.220	$u_{\Delta sc}$	0.26	0.0697	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.20	1.4400	
					Combined standard uncertainty	u_c	4.9281	nmol/mol
					Expanded uncertainty	U	9.8561	nmol/mol
					Relative expanded uncertainty	W	8.21	%
					Maximum allowed expanded uncertainty	W_{req}	15	%

8. recommendations for use

Tasks during the period of unattended operation (4 weeks)

The following checks are required on a regular basis:

- Regular visual inspections / telemetric monitoring
- Analyser status
- Error warnings
- Replacement of the Teflon filter in the sample gas inlet
- Zero and span point checks with appropriate test gases

For all intents and purposes the manufacturer’s instructions shall be considered.

Further details are provided in the manual.

Immissionsschutz/Luftreinhaltung

Dipl.-Ing. Guido Baum	Dipl.-Ing. Karsten Pletscher

Köln, 08 October 2013
936/21221977/C_EN

9. Literature

[1] VDI Guideline 4202, Sheet 1, "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants", September 2010

[2] VDI Guideline 4203, Sheet 3, "Testing of automated measuring systems - Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", September 2010

[3] European Standard DIN EN 14625: Ambient air – Standard method for the measurement of the concentration of ozone by ultraviolet photometry, December 2012

[4] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

10. Annex

Annex 1 Manual

Annex 1

Manual

ecotech
environmental monitoring solutions

Serinus 10
Ozone Analyser

User Manual

Version: 2.1

www.ecotech.com

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Table of Contents

List of Figures

List of Tables

Manufacturer's Statement

Thank you for selecting the Ecotech Serinus 10 Ozone Analyser.

The Serinus series is the next generation of Ecotech designed and manufactured gas analysers. The Serinus 10 will perform ozone measurements over a range of 0-20ppm with a lower detectable limit of 0.5 ppb.

This User Manual provides a complete product description including operating instructions, calibration, and maintenance requirements for the Serinus 10.

Reference should also be made to the relevant local standards which should be used in conjunction with this manual. Some relevant standards are listed in the references section of this manual.

If, after reading this manual you have any questions or you are still unsure or unclear on any part of the Serinus 10 then please do not hesitate to contact Ecotech or your local Ecotech distributor.

Please help the environment and recycle the pages of this manual when you have finished using it.

Notice

The information contained in this manual is subject to change without notice. Ecotech reserves the right to make changes to equipment construction, design, specifications and /or procedures without notice.

CAUTION

Hazardous voltages exist within the analyser. The analyser lid should be closed and when the analyser is left unattended or turned on. Ensure the power cable, plugs and sockets are maintained in a safe working condition.

Safety Requirements

To reduce the risk of personal injury caused by electrical shock, follow all safety notices and warnings in this documentation.

If the equipment is used for purposes not specified by Ecotech, the protection provided by this equipment may be impaired.

Replacement of any part should only be carried out by qualified personnel, using only parts specified by Ecotech as these parts meet stringent Ecotech quality assurance standards. Always disconnect the power source before removing or replacing any components.

Warranty

This product has been manufactured in an ISO 9001/ISO 14001 facility with care and attention to quality.

The product is subject to a 24-month warranty on parts and labour from date of shipment. The warranty period commences when the product is shipped from the factory. Lamps, fuses, filters batteries and other consumable items are not covered by this warranty.

Each analyser is subjected to a vigorous testing procedure prior to despatch and will be accompanied with a parameter list and a multipoint calibration check thereby enabling the analyser to be installed and ready for use without any further testing.

Service and Repairs

Our qualified and experienced technicians are available to provide fast and friendly service between the hours of 8:30am – 5:00pm AEST Monday to Friday. Please contact either your local distributor or Ecotech regarding any questions you have about your analyser.

Service Guidelines

In the first instance, please call or email us if you are experiencing any problems or issues with your analyser.

If you are within Australia or New Zealand please contact our service response centre via email on service@ecotech.com.au or call +61 (0)3 9730 7800

If outside of Australia and New Zealand please email our international support department at intsupport@ecotech.com or call +61 (0)3 9730 7800

If we cannot resolve the problem through technical support, please email the following information:

- Name and phone number.
- Company name.
- Shipping address.
- Quantity of items being returned.
- Model number/s or a description of each item.
- Serial number/s of each item (if applicable).
- A description of the problem.
- Original sales order or invoice number related to the equipment.

When you email us we will assign a Return Material Authorisation (RMA) number to your shipment and initiate the necessary paperwork to process your equipment within 48 hours.

Please include this RMA number when you return equipment, preferably both inside and outside the shipping packaging. This will ensure you receive prompt service.

CE Mark Declaration of Conformity

This declaration applies to the Serinus 10 Ozone Analyser as manufactured by Ecotech Pty. Ltd. of 1492 Ferntree Gully Rd, Knoxfield, VIC, 3180, Australia. The instrument to which this declaration relates is in conformity with the following European Union Directives:

Council Directive of 15 December 2004 on the approximation of the laws of Member States relating to electromagnetic compatibility (2004/108/EC)

The following standard was applied:

EN 61326-1:2006	**Electrical Equipment for measurement, control and laboratory use – EMC Requirements – Part 1: General requirements.**

Immunity Requirements EN61326-1

IEC-61000-4-2	Electrostatic discharge immunity
IEC-61000-4-3	Radiated RF immunity
IEC-61000-4-4	Electrical fast transient burst immunity
IEC-61000-4-5	Surge immunity
IEC-61000-4-6	Conducted RF Immunity
IEC-61000-4-11	Voltage dips and interruption immunity

Electromagnetic Compatibility EN61326-1

CISPR-11	Radiated RF emission measurements
CISPR-11	Mains Terminal RF emission measurements
IEC-61000-3-3	Mains Terminal voltage fluctuation measurements
IEC-61000-3-2	Power Frequency harmonic measurements

Council Directive of 12 December 2006 on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limits (2006/95/EC)

The following standard was applied:

EN 61010-1:2001	**Safety requirements for electrical equipment, for measurement control and laboratory use – Part 1: General requirements**

For protection against:

Electric shock or burn

Mechanical HAZARDS

Excessive temperature

Spread of fire from the equipment

Effects of radiation, including laser sources and sonic and ultrasonic pressure

Claims for Damaged Shipments and Shipping Discrepancies

Damaged Shipments

Inspect all instruments thoroughly on receipt. Check materials in the package(s) against the enclosed packing list. If the contents are damaged and/or the instrument fails to operate properly, notify the carrier and Ecotech immediately.

The following information is necessary to support claims:

- Original freight bill and bill of lading.
- Original invoice or photocopy of original invoice.
- Copy of packing list.
- Photographs of damaged equipment and packaging.
- Contact your freight forwarder for insurance claims.
- Retain packing material for insurance inspection.

You should keep a copy of the above for your records.

Refer to the instrument name, model number, serial number, sales order number, and your purchase order number on all claims.

Shipping Discrepancies

Check all packages against the packing list immediately on receipt. If a shortage or other discrepancy is found, notify the carrier and Ecotech immediately. We will not be responsible for shortages against the packing list unless they are reported promptly (within 7 days).

Contact Details

Head Office
1492 Ferntree Gully Road, Knoxfield VIC Australia 3180
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Email: info@ecotech.com
Service: service@ecotech.com.au
International Support: intsupport@ecotech.com
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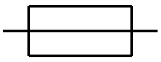
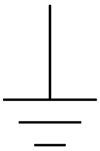
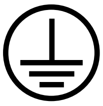
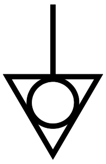
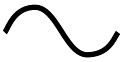
Internationally Recognised Symbols on Ecotech Equipment

	Electrical fuse	IEC 60417-5016
	Earth (ground) terminal	IEC 60417-5017
	Protective conductor terminal	IEC 60417-5017
	Equipotentiality	IEC 60417-5021
	Alternating current	IEC 60417-5032
	Caution, hot surface	IEC 60417-5041
	Caution, risk of danger. Refer to accompanying documents	ISO 7000-0434
	Caution, risk of electric shock	ISO 3864-5036

Manual Revision History

Manual PN: M010026

Current revision: 2.1

Date released: 29 March 2013

Description: User Manual for the Serinus 10 Ozone Analyser

This manual is the full user manual for the Serinus 10 Ozone Analyser. This manual contains all relevant information on theory, specifications, installation, operation, maintenance and calibration. Any information that cannot be found within this manual can be obtained by contacting Ecotech.

Edition	Date	Summary	Pages
1.0	September 2008	Initial Release	All
1.1	December 2008	Menu updates and general corrections	All
1.2	March 2009	New maintenance procedures Updated analyser setup Small corrections New menu items added	36, 46 12-13 Various 19-30
1.3	November 2009	Serinus downloader added Internal pump option added USB - Advanced Parameters updated Minor corrections	89-89 114 128 Various
1.4	September 2010	CE conformity added Parts list updated Pressurised zero valve added Updates to rack mount option Updates to Serinus downloader Update to 25 pin I/O Update to network communications	iv 100 117 110 89-89 89 89
2.0	July 2012	New chassis Update menu system Add Bluetooth menu Serinus Remote Android App Rack mount procedure update Analog output calibration	Various
2.1	March 2013	Formatting updates	All

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1. Introduction

1.1 Description

The Serinus 10 Ozone Analyser uses non-dispersive ultraviolet (UV) absorption technology to measure ozone to a sensitivity of 0.5ppb in the range of 0-20ppm. The Serinus 10 measures O_3 with the following components and techniques:

- Mercury vapour lamp – to provide detector input.
  (254nm UV Light Source)
- Photodiode detector – to capture the measurement response.
  Detects the ratio of transmitted light, thereby giving the concentration of ozone.
- Ozone scrubber – to establish the background response.
  As ozone is not the only atmospheric gas that absorbs the particular wavelength of UV light.

A microprocessor programmed with Serinus firmware monitors the detector response and many other parameters, such that the O_3 concentration is automatically corrected for gas temperature and pressure changes and referenced to 0°C, 20°C or 25°C at 1 atmosphere. This allows the Serinus 10 to sample in the most common measurement range for O_3.

The U.S. EPA has designated the Serinus Ozone Analyser as an Equivalent Method and SIRA has designated it as an EN approved instrument.

1.2 Specifications

1.2.1 Measurement

Range:

0-20ppm auto ranging.

USEPA designated range: 0-0.5 ppm.

MCERTS EN certification range: 0 to 250 ppb.

Lower detectable limit: 0.5ppb.

1.2.2 Precision/Accuracy

Precision:

0.5ppb at <100 ppb otherwise 0.2% of reading, whichever is greater.

Linearity:

<1% of full scale.

Noise:

<0.25 ppb.

Analog output: 0.25ppb or 0.1% of analog output full scale, whichever is greater.

Sample Flow Rate:

0.5 slpm

1.2.3 Calibration

Zero Drift:

Temperature dependant:	1.0ppb per °C.
24 hours:	< 0.3 ppb.
7 days:	< 0.3ppb.

Span Drift:

Temperature dependant:	0.1% per °C.
7 days:	0.5% of reading.

1.2.4 Power

Operating Voltage:

99 to 132 VAC (57-63Hz) or via switch 198 to 264 VAC (47 to 53 Hz).

U.S. EPA designated range: 105 to 125 VAC, 60 Hz.

Power Consumption:

85VA maximum (typical at start-up).

65VA after warm-up.

Fuse Rating:

20x5mm, T 250V, 5A (slow blow).

1.2.5 Operating Conditions

Ambient Temperature Range:

0 °C to 40 °C (32 °F to 104 °F).

U.S. EPA designated range: 20 °C to 30 °C.

Sample Pressure Dependence:

5% change in pressure produces less than a 1% change in reading.

Maximum altitude: 3000m above sea level.

1.2.6 Communications

- USB port connection on rear panel.
- Bluetooth (digital communication via Android App).
- TCP/IP Ethernet network connection (optional).
- RS232 port #1: Normal digital communication or termination panel connections.
- RS232 port #2: Multidrop port used for multiple analyser connections on a single RS232.
- USB memory stick (front panel) for data logging, event logging and parameter/configuration storage.

Protocols

- Modbus RTU/TCP, Bavarian, EC9800, Advanced

25 pin I/O Port

- Analog output (menu selectable current or voltage output).
  - Current output of 0-20 mA, 2-20 mA or 4-20 mA.
  - Voltage output of 0 to 5 V, with menu selectable zero offset of 0V, 0.25V or 0.5V.
  - Range: 0 to full scale from 0-0.05 ppm to 0-20 ppm.
- 8 digital outputs, open collector 150mA each.
- 8 digital inputs, 0-5VDC, CAT I rated.
- Three analog voltage inputs (0-5VDC) CAT I rated.

1.2.7 Physical Dimension

Case Dimensions:

Rack Length (front to rear):	597 mm (23.5 inches)
Total Length (w/ latch release):	638 mm (25.1 inches)
Chassis Width:	418 mm (16.5 inches)
Front Panel Width:	429 mm (16.9 inches)
Chassis Height:	163 mm/Uses 4RU (6.4 inches)
Front Panel Height:	175 mm (6.9 inches)
Weight:	17.2 kg

1.2.8 Certifications

- U.S. EPA approval (EQOA-09-118-10)
- EN approval (Sira MC 100165/02)
- Ultraviolet photometry method EN14625
- Determination of Ozone AS3580.6.1 Australian/New Zealand Standards

1.3 Nomenclature

Span:	A gas sample of known composition and concentration used to calibrate/check the upper range of the instrument (ozone).
Zero:	Zero calibration uses zero air (ozone scrubbed ambient air) to calibrate/check the lower range of the instrument.
Background:	Is the reading of the sample without ozone present in the measurement cell.
Zero Drift:	The change in instrument response to zero air over a period of continuous unadjusted operation.
Zero Air:	Purified air in which the combined effect of the concentration of impurities is less than 1% of the relevant midrange of the analyser. Sufficient purified air can be obtained by passing dry ambient air through an activated charcoal filter and a particulate filter.
Ext. Span Source:	Span gas that is delivered via an external ozone generator.
Sample Air:	Sample air is defined as the sample before it has entered the measurement cell, as distinguished from the exhaust air.
Exhaust Air:	Exhaust air is the sample air after it has passed through the measurement cell and is moving towards being expelled from the analyser.
ID and OD:	These are measurements of tubing. ID is the internal diameter of tubing, OD is the outer diameter.

1.4 Background/Theory

Within the industrial sector, ozone is not directly emitted to the atmosphere. Its formation is normally due to the reaction of sunlight on air containing hydrocarbons and nitrogen oxides. Ozone in the ambient air is also found to create other pollutants in the air, such as components of smog.

Ground-level ozone has become a global air pollution problem. According to measurements at remote background sites), the ozone background concentration has increased by about 2 ppb (approximately 6 %) per decade since 1980 and is expected to rise further.

Ozone has been found to affect human health (when close to ground level) by harming the respiratory and immune system. People with pre-existing respiratory damage or diseases are more likely to suffer from the effects of ozone.

1.4.1 Measurement Theory

Ozone is measured by UV absorption analysis. The UV photometer determines the concentration of ozone (O_3) in a sample gas at ambient pressure by detecting the absorption of UV radiation in a glass absorption tube. The Serinus 10 follows these principles and measurement techniques:

- Ozone shows strong absorption of UV light at 254nm.
- Sample air is passed into the glass absorption tube (measurement cell).
- Within the measurement cell a single beam of UV radiation (from a mercury vapour lamp) passes through the sample and is absorbed by the O_3.
- The solar blind vacuum photodiode detects any UV that is not absorbed.

- The strength of the UV signal being detected is proportional to the amount of UV light being absorbed by O_3.
- The Serinus 10 analyser uses the Beer-Lambert relationship (Beer-Lambert Law) to calculate the ozone concentration.
- O_3 is not the only gas that absorbs UV (254nm), SO_2 and aromatic compounds also absorb radiation at this wavelength. To eliminate these interferences a second cycle is performed. Sample air is passed through an ozone scrubber, removing ozone but allowing all interfering gases through. Therefore, accurately measuring the effect of interfering gases. This effect is then removing them from the sample measurement signal. This enables the accurate measurement of ozone without the influence of interferrants.
- The microprocessor and electronics of the Serinus 10 control, measure, and correct for all the major external variables to ensure stable and reliable operation.

1.4.2 Kalman Filter Theory

The digital Kalman filter provides an ideal compromise between response time and noise reduction for the type of signal and noise present in ambient air analysers.

The Kalman filter enhances measurements by modifying the filter time base variable, depending on the change rate of the measured value. If the signal rate is changing rapidly, the instrument is allowed to respond quickly. When the signal is steady, a long integration time is used to reduce noise. The system continuously analyses the signal and uses the appropriate filtering time.

1.5 Instrument Description

The major components of the Serinus 10 are described below:

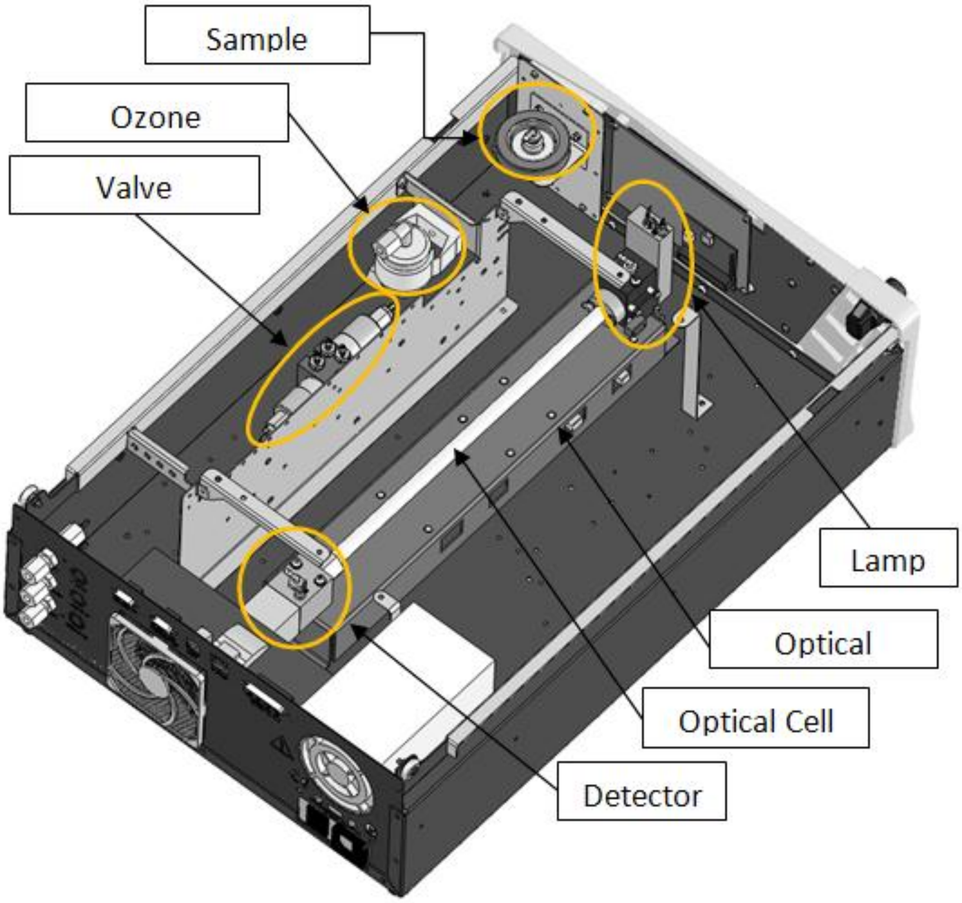

Figure 1 – Major components

1.5.1 Particulate Filter

The particulate filter is a Teflon 5 micron (µm) filter with a diameter of 47mm. This filter eliminates all particles larger than 5µm that could interfere with sample measurement.

1.5.2 Ozone Scrubber

The ozone scrubber uses manganese dioxide (MnO_2) to selectively destroy ozone by catalytic means from the sample air while all other interferants remain. This scrubber is used to remove the effect interferants have on the final O_3 measurement by calculating their UV absorption and subtracting it from the O_3 measurement.

Note: High concentrations of aromatic hydrocarbons may interfere with ozone measurements.

1.5.3 Valve Manifold

The instrument features a three way valve manifold to enable selection of either, external calibration gas, ambient air, or O_3 free ambient air.

1.5.4 Optical Bench

The optical bench consists of the lamp, detector, and optical cell.

1.5.5 Lamp

The UV source is a mercury vapour lamp that emits radiation around 254nm.

Lamp Driver PCB

This driver uses a high voltage and high frequency switching supply to start and maintain the UV lamp at a constant intensity. The lamp current is set by the microprocessor and is maintained at 10 mA. The lamp driver PCB is located under the UV absorption cell.

CAUTION

The lamp driver PCB contains high voltages. Ensure instrument is turned off before accessing this component.

Lamp Power Supply

The high frequency lamp driver is set for 10mA power output at 800- 1100volts.

Note: Switch S1 indicates the lamp type**.**

The correct setting must be used or damage to the electronics will occur. For the Serinus 10 (which measures O_3), switches 1 & 2 must be in the "Off" position, and switches 3 & 4 must be in the "On" position (refer to Figure 2).

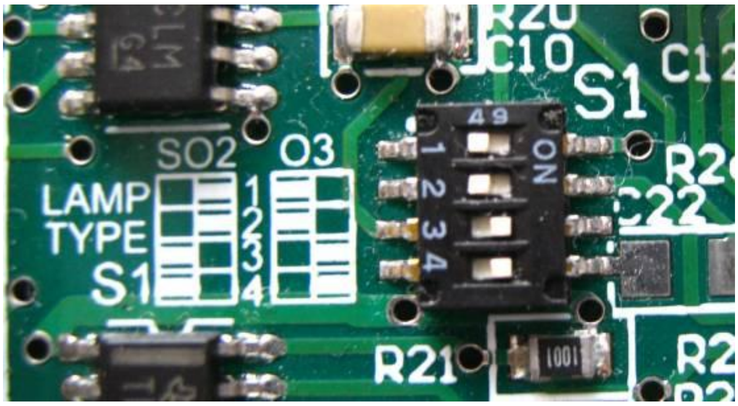

Figure 2 - Lamp type switch setting

1.5.6 Optical Cell

The optical cell is a glass tube with a UV source at one end and a detector at the other. UV radiation is sequentially absorbed by sample gas and ozone free sample gas over the length of the reaction cell. The remaining light reaching the detector is measured and used to calculate the O_3 concentration.

1.5.7 Detector

The detector is a solar blind vacuum diode sensitive only in the spectral region where O_3 absorbs (254nm). This sensor is used to monitor the intensity of the residual light after absorption in the reaction cell. The UV detector preamplifier converts the detector's current output into a voltage level for the main PCB A/D converter.

1.5.8 Main Controller PCB

The main controller PCB controls all the processes within the instrument. It contains a battery backed clock, calendar and an on-board microprocessor. The main controller PCB is located on top of the other components with the analyser. The PCB pivots on hinges to allow access to the components underneath.

CAUTION

Never place objects on top of the main controller PCB as it may result in damage.

1.5.9 Pressure PCB

The pressure PCB contains an absolute pressure transducer to measure cell pressure. The sample pressure is used by the CPU to calculate both the O_3 concentration and cell flow rate.

1.5.10 Power Supply

The power supply is a self-contained unit housed in a steel case.

It has a selectable input voltage of 115 or 230VAC 50/60 Hz and an output voltage of 12 VDC power for distribution within the analyser.

Note: Input voltage can be manually changed by sliding the red switch left (230) for 220-240V or right (110) for the 100-120V. Ensure the switch is set to the correct voltage (from supply) before switching on.

1.5.11 On/Off Switch

Located on the back panel (bottom right facing the rear of the instrument).

1.5.12 Communications

Communication between the analyser and either a data logger, laptop or network can be performed with the following communication connections located on the back panel.

RS232 #1

This port is designed to be used for simple RS232 communication.

RS232 #2

This port is designed to be used for simple RS232 communication, or in multidrop configuration.

USB

This port can be used for instrument communication and is also good for quickly downloading data, onsite diagnostics, maintenance and firmware upgrades.

TCP/IP (optional)

This port is best used for remote access and real-time access to instruments when a network is available to connect with.

External I/O Port

The analog/digital port sends and receives analog/digital signals to other devices. These signals are commonly used to activate gas calibrators or for warning alarms.

Analog Outputs

The analyser is equipped with three analog outputs. Menu selectable as either voltage output 0-5VDC, or current output 0-20, 2-20, 4-20 mA.

Analog Inputs

The analyser is also equipped with three analog voltage inputs (0-5VDC) with resolution of 15 bits plus polarity.

CAUTION
Exceeding these voltages can permanently damage the instruments and void warranty.

Digital Status Inputs

The analyser is equipped with 8 logic level inputs (0–5VDC) for the external control of zero/span calibration sequences.

CAUTION
Exceeding these voltages can permanently damage the instruments and void warranty.

Digital Status Outputs

The analyser is equipped with 8 open collector outputs which will convey instrument status conditions and warning alarms such as no flow, sample mode, etc.

Bluetooth

This allows for remote access of the analyser to any Android device with the “Serinus Remote” Application installed on it. Uses Bluetooth to control the analyser, view parameters, download data and construct real-time graphs.

2. Installation

2.1 Initial Check

Packaging

The Serinus 10 is transported in packaging which is specifically designed to minimise the effects of shock and vibration during transportation. Ecotech recommends that the packaging be kept if there is a likelihood that the instrument is going to be relocated.

Note: The red plastic caps that seal the pneumatic connections during transport must be removed prior to operation.

Opening the Instrument

To check the interior of the instrument:

1. Undo the screws located on the rear panel.
2. Open the chassis lid by releasing the latch (pressing the button) located on the front panel in the top left-hand corner, then slide the lid backwards.
3. To completely remove the lid, slide the lid backwards until the rollers line up with the gaps in the track and pull the lid upwards to remove from the instrument (refer to Figure 3).
4. Check that all pneumatic and electrical connectors are connected.

Check for any visible and obvious damage. If damage exists contact your supplier and follow the instructions in Claims for Damaged Shipments and Shipping Discrepancies at the front of this manual.

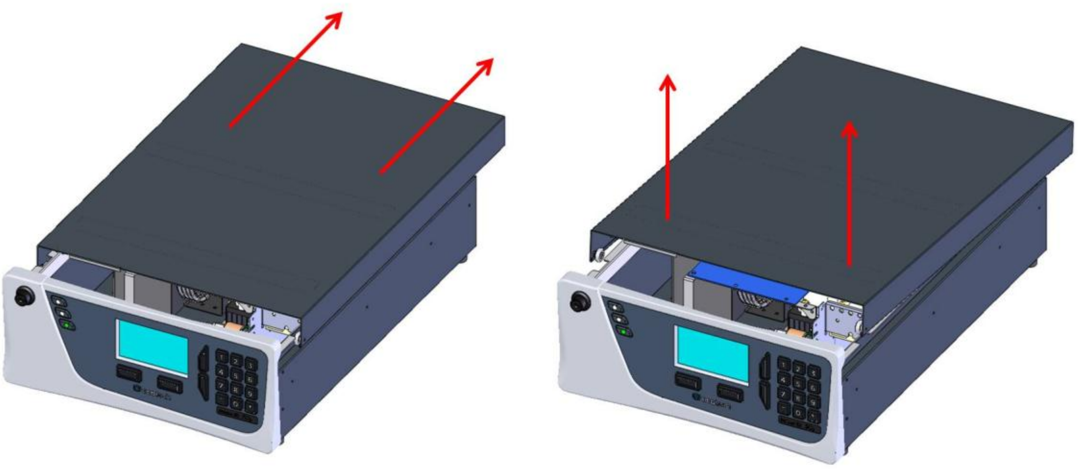

Figure 3 – Opening the instrument

Items Received

• Ecotech Serinus 10 instrument		PN: E020010
• Software CD		PN: S040001
• Manual		PN: M010026 (hardcopy optional)
• USB Stick		PN: H030021
• Power Cord (120V)*		PN: C040007
• Power Cord (240V)*	Australia	PN: C040009
	Europe	PN: C040008
	UK	PN: C040010

*The power cord received depends on the power supply of the country (120V or 240V).

Note: Please check that all these items have been delivered undamaged. If any item appears damaged, please contact your supplier BEFORE turning the instrument on.

2.2 Mounting/Siting

When installing the instrument the following points must be taken into account:

- The analyser should be placed in an environment with minimal dust, moisture and variation in temperature (20-30°C for U.S. EPA equivalency).
- For best results the analyser should be located in a controlled environment with temperature and humidity controlled (air conditioned shelter) set to 25-27°C.
- Whether in a rack or placed on a bench, the instrument should not have anything placed on top of it or touching the case.
- Instruments should be sited with easy access to the front panel (instrument screen/USB flash) and to the back panel (communication ports/pneumatic connections).
- It is recommended that sample line be as short as possible and/or a heated manifold be used for sampling (minimising moisture condensation in the sample).
- Do not pressurise the sample line under any circumstances. Sample should be drawn through the instrument under atmospheric pressure. This should be done either by the internal pump option (if installed) or by an external vacuum pump connected to the exhaust port of the analyser.
- When supplying span gas, ensure the flow is approximately 1.0 lpm and excess is sufficiently vented.

Note: The power on/off switch is accessible from the rear of the instrument only. Site the analyser so that the on/off power switch is accessible.

2.3 Instrument Set-up

After siting the instrument the following procedures should be followed to ready the analyser for monitoring.

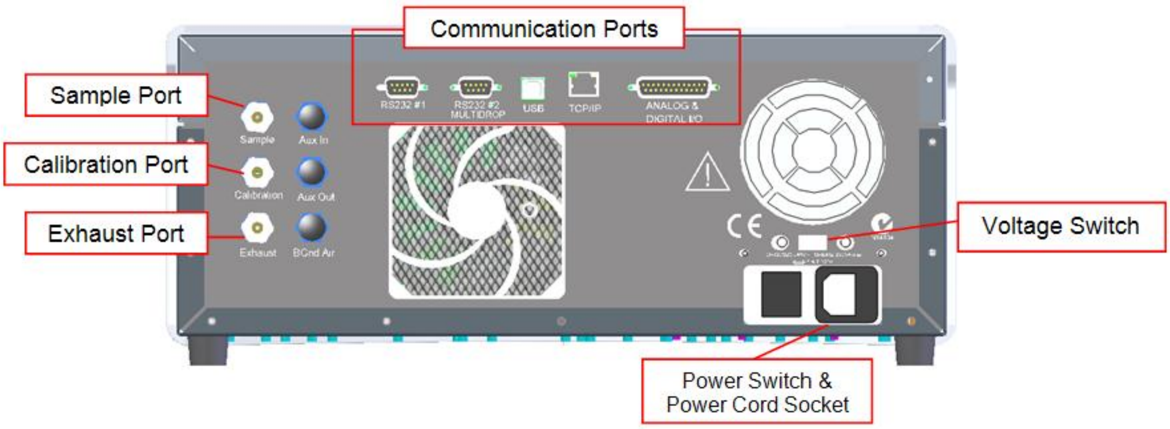

Figure 4 – Instrument back panel

2.3.1 Pneumatic Connections

The Serinus 10 contains three pneumatic ports on the back panel of the analyser; the sample port, the calibration port and the exhaust port. All tubing and fittings used should follow the instructions below:

- Must be made of Teflon® FEP material, Kynar®, stainless steel, glass or any other suitably inert material.
- Sample line should be no more than 2 meters in length with ⅛ inch ID, ¼ inch OD.
- Sample inlet pressure should not exceed 5 kPa above ambient pressure.
- Tubing must be cut squarely and any burrs removed.
- Remove the inlet port nut, then insert the tubing through the back of the nut with the tube extending 1 inch through front.
- Place the tubing into the port until it hits the tube stop located inside the fitting.
- Place the nut back onto the fitting and tighten until (clockwise) finger tight.
- Nuts should be re-tightened when instrument reaches operating temperature.

Sample Port

The sample port must be connected to an ambient source of sample air. When using a sample manifold the Serinus requires at least 1 slpm delivered to the sample manifold (0.5 slpm for measurement plus approximately 0.5 overflow).

Calibration Port

The calibration port should be connected to the span/zero source. It is recommended that a gas calibrator (Ecotech's GC1100TS) or Photometer (Ecotech's EC9811) be used which can deliver precise concentrations of ozone.

Exhaust Port

The sample air is expelled from the analyser through the exhaust port. The exhaust tubing should be fitted to a vacuum pump (minimum: 1 SLPM at 50 kPa) if the internal pump is not installed in your analyser.

Note: It is recommended that exhaust air is expelled into an unoccupied area. Furthermore, the exhaust must be a suitable distance from the sample inlet to avoid influencing the ambient measurements.

2.3.2 Power Connections

When connecting the power source the following must be adhered to:

CAUTION

The following points MUST be followed. Incorrect setup and activation of instrument may cause damage and will void warranty.

- Verify that the red switch (above power switch) is switched to the correct setting (230V or 110V).
- A three pin power plug (with ground) must be used with an earthed power socket (3 pin).
- Connect the power plug into the mains power point and turn the power switch on.

2.3.3 Communications Connections

There are a number of ways to communicate with the analyser:

RS232 #1

Connect this port to a data logger (such as WinAQMS) with an RS232 cable.

RS232 #2

Connect the RS232 cable from the instrument to a computer, data logger or in a multidrop formation.

This is used to configure the computer/data logger software for data export/remote control.

Note: When using multidrop ensure each analyser is given a unique instrument ID.

USB

Connect USB cable to computer and run either the Serinus downloader program or WinAQMS logger.

TCP/IP (optional)

Plug in a network cable (this cable should be attached to a network) and use the Serinus Downloader program to access the instrument and download data. The Serinus downloader is supplied on the utilities CD provided with the instrument.

Analog/Digital

This port is used to send and receive analog and digital signals. It is normally used to connect with a gas calibrator or to activate alarm signals.

Each instrument contains 8 digital inputs, 8 digital outputs, 3 analog inputs and 3 analog outputs.

Bluetooth

Connection is enabled using Ecotech's "Serinus Remote" Android Application.

Use the "Serinus Remote" Android Application to access instrument and download data. It is available for download directly from the Google Play Store. Search for "Ecotech Serinus Remote".

2.3.4 Analyser Set-up

1. Ensure that the USB memory key is installed.
2. Check that the battery is turned on at the main controller PCB (refer to Figure 5).
3. Turn on the instrument and allow it to warm up (refer to Section 3.1).
4. Check/set time and date (refer to Section 3.5.8).
5. Set the digital filter to the desired monitoring option.
6. Set the internal data logging options.
7. Set the analog/digital inputs and outputs settings.
8. Leave the instrument to warm up and stabilise for 2-3 hours.
9. Perform a pressure sensor check (refer to Section 6.4.8).
10. Perform a leak check (refer to Section 6.4.3).
11. Perform a multipoint calibration (refer to Section 5).
12. The instrument will now be ready for operation.

2.4 U.S. EPA Equivalent Set-up

The Serinus 10 is designated as equivalent method EQOA-0809-187 by the U.S. EPA (40 CFR Part 53). The Serinus 10 must be used under the following conditions to satisfy its equivalency:

Range: 0-500ppb

Ambient temperature: 20-30°C

Line voltage: 105 to 125 VAC, 60 Hz

Pump: Ecotech internal or external pump

Filter: 5 micron PTFE filter must be installed in front of the sample inlet (zero and span gas must pass through this filter).

The analyser must be operated and maintained in accordance with this user manual.

The following menu selections must be used:

Measurement Settings

Background interval: Enabled

Calibration Menu

Span comp: Disabled

Service→Diagnostics Menu

Pres/Temp/Flow Comp: On

Diagnostic mode: Operate

Control loop: Enabled

The Serinus 10 analyser is designated U.S. EPA equivalent method with or without the following options/items:

- Internal pump.
- Rack mount assembly.
- Internal zero/span assembly (IZS).
- Optional ethernet port.

2.5 EN Type Approval Set-up

The Serinus 10 has been certified to MCERTS Performance Standards for Continuous Ambient Air Quality Monitoring Systems. The certificate number is Sira MC100165/00. The Serinus 10 must be used under the following conditions to qualify as equivalent:

Range: 0-250 ppb

Ambient temperature: 0-30°C

The analyser must be operated and maintained in accordance with this user manual.

The following menu selections must be used:

Calibration Menu

Span comp: Disabled

Service→Diagnostics Menu

Pres/Temp/Flow Comp: On

Diagnostic mode: Operate

Control loop: Enabled

2.6 Transporting/Storage

Transporting the Serinus should be done with great care. It is recommended that the packaging the Serinus was delivered in should be used when transporting or storing the instrument. The following points should be followed:

1. Turn off instrument and allow it to cool down.
2. Remove all pneumatic, power and communication connections.
3. If storing over long period (6 months) turn the battery off by switching the switch on the main processor board (shown in Figure 5) to the left.
4. Remove the instrument from the rack.
5. Replace its red plugs into the pneumatic connections.
6. Place the instrument back in to its plastic bag with desiccant packs and seal the bag (Ideally the bag it was delivered in).
7. Place the instrument back into the original foam and box it was delivered in. If this is no longer available find some equivalent packaging which provides protection from damage.
8. The instrument is now ready for long term storage or transportation.

Note: After transport or storage the instrument must be set up and calibrated (refer 5).

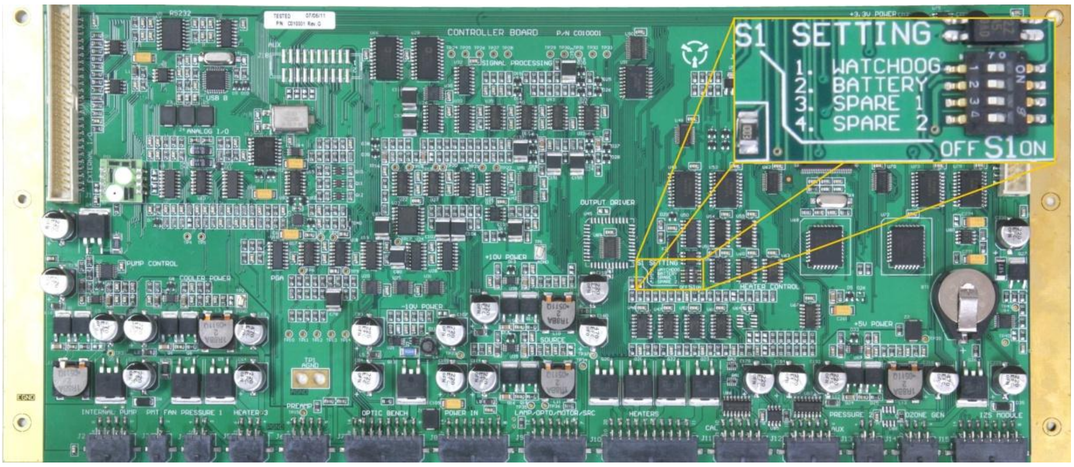

Figure 5 - Switching the battery off

3. Operation

3.1 Warm-up

Once the instrument is turned on it will adjust itself to prepare for monitoring. No measurements are taken during the warm-up period.

The main display indicates the following warm-up activities:

Lamp Adjust

The microprocessor automatically adjusts the lamp's current (10mA) for a stable (reference voltage) signal/output (2 minutes).

Ref Stabilise

The microprocessor sets the reference voltage to 2.8 - 3.2v output and creates a stable output signal.

Zero Adjust

The microprocessor sets the coarse and fine zero pots for a zero detector output.

Zero Stabilise

Waits until the zero voltage signal is stable.

After this warm-up has completed the instrument will immediately begin making measurements.

3.2 General Operation

The Serinus is operated with the use of 4 sets of buttons. There are the selection buttons (1), scrolling buttons (2), keypad (3) and traffic light indicators (4).

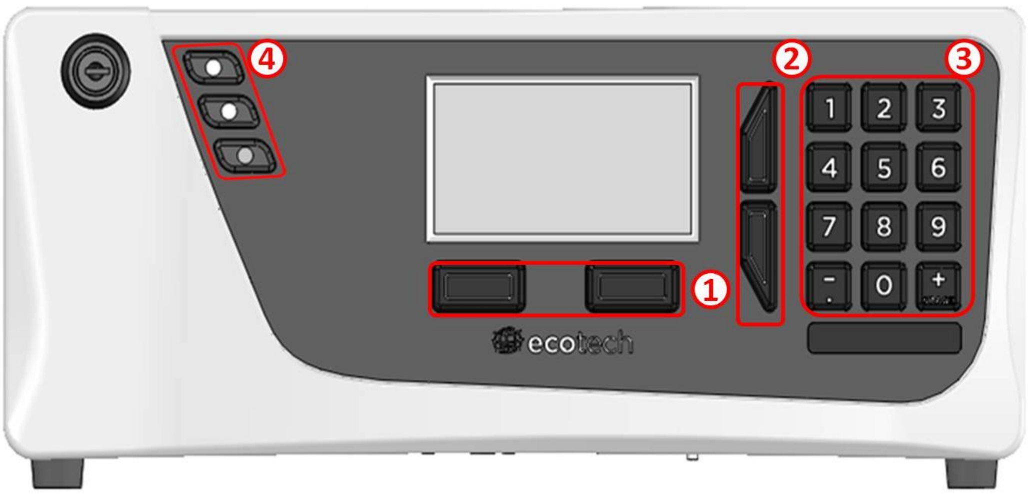

Figure 6 – Serinus front panel

Selection Buttons (1)

The selection buttons will perform the function specified directly above it on the screen. Generally this involves opening a menu, editing a value, accepting or cancelling an edit, or starting an operation.

Scrolling Buttons (2)

The scrolling buttons allow users to scroll up and down through menus or selection boxes. The scrolling buttons are also used to scroll side to side through editable fields such as: dates, times, numbers etc.

On the main screen these buttons are used for adjusting the screen contrast. Press and hold the up button to increase contrast; press and hold the down button to decrease.

Keypad (3)

The keypad contains numbers 0-9, decimal point/minus key ($\overset{-}{.}$) and a space/plus key ($\overset{+}{\text{SPACE}}$). The number keys are used to input numbers; in those cases where letters can be entered, the number keys act like a telephone keypad.

The ($\overset{+}{\text{SPACE}}$) and key ($\overset{-}{.}$) button functions depend on context. When editing a floating point number, the key ($\overset{-}{.}$) inserts a negative sign if the editing cursor is at the start of the number and negative signs are allowed. Otherwise it moves the decimal place to the current cursor location. The ($\overset{+}{\text{SPACE}}$) key inserts a positive sign if the cursor is at the start of the number; otherwise it enters a space.

For non-floating point numbers, these keys usually increment or decrement the current value by 1. When editing the month field of a date, the ($\overset{+}{\text{SPACE}}$). and ($\overset{-}{.}$) key change the month.

Instrument Status Lights (4)

Located in the top left corner, these lights indicate the status of the instrument.

- A flashing red light indicated that the instrument has a major failure and is not functioning.
- An orange light indicates there is a minor problem with the instrument, but instrument may still take measurements reliably.
- A green light indicates that the instrument is working and there are no problems.

In the case of a yellow or red light enter the **Main Menu** → **Analyser State** → **Status Menu** to find which components are failing (refer to Section 3.5.4).

The green status button will cancel any open edit box or menu and return to the main display.

If no instrument status lights are on and the keypad is backlit, then this indicates that the instrument is running the Bootloader.

3.3 Main Display

The main display is composed of seven parts: the readings, the error/status line, the time, the instrument activity line, selection buttons, the concentration units and USB status.

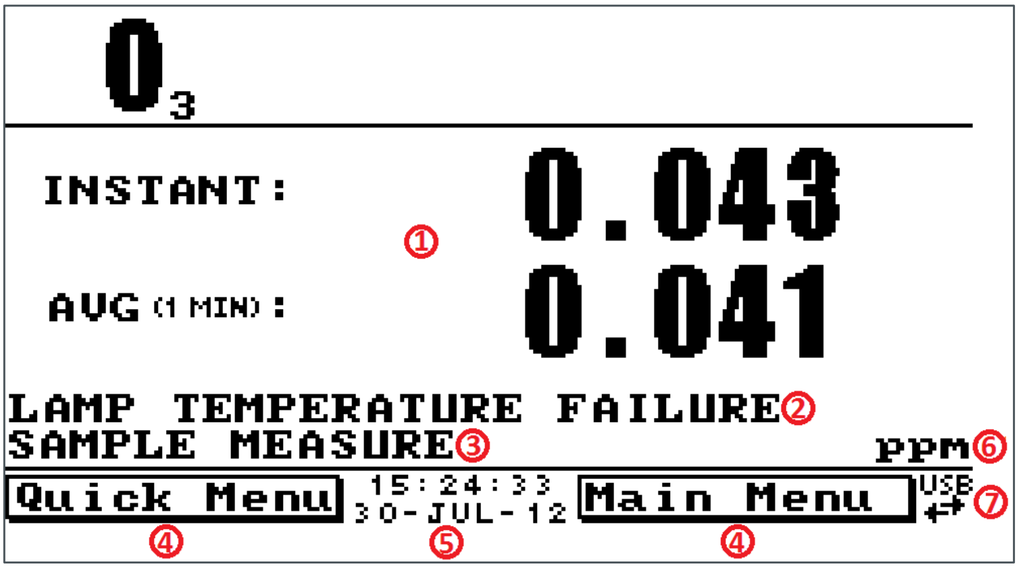

Figure 7 - Main screen

Reading (1)

Displays the concentration being measured in real time. The display can be configured to show just the instantaneous data or the instantaneous and average data (refer to Section 3.5.8).

Error/Status Line (2)

The error/status line provides users with information on any problems the instrument may have. It includes all the errors and status conditions contained in the **Status Menu** (refer to Section 3.5.4).

Instrument Activity (3)

This line shows what function the instrument is currently performing. Generally, it will show three groups of actions; warm-up, measurement or calibration.

Selection Buttons (4)

These buttons are used on the main screen to enter one of two menus. The **Quick Menu** (3.5.1) contains all information and features necessary for scheduled maintenance. The **Main Menu** (refer to Section 3.5.2) contains all information and fields available to users and is generally only used during initial setup.

Time and Date (5)

The time and date are displayed in between the menu buttons at the bottom of the screen.

Concentration Units (6)

The instrument units are displayed in the bottom right hand corner of the display.

USB Detection (7)

A USB symbol will be displayed in the bottom right corner when the USB memory stick is plugged in (behind front panel). If the USB symbol is not shown the USB memory stick should be reattached. Underneath the USB, symbols arrows may be displayed which indicates data transfer. The USB memory stick must not be removed whilst this is happening.

Note: To safely remove the USB memory stick, navigate to the **Quick Menu** and use the "Safely Remove USB Stick" function (refer to Section 3.5.1).

3.4 Measurement

A measurement consists of two parts: the background cycle and the sample cycle. The background cycle measures ozone free air to determine if any UV absorption is occurring without ozone present. The sample cycle measures sample air with ozone present and uses the background measurement to subtract the effects of any interferants.

Background Cycle

- Background Fill — Measurement cell fills with O_3 free.
- Background Measure — Measurement of O_3 free air.

Sample Cycle

- Sample Fill — Measurement cell fills with sample.
- Sample Measure — Measurement of sample air.

3.5 Menus and Screens

The menu system is divided into two sections, the **Quick Menu** and the **Main Menu**. The **Quick Menu** contains all information and operations necessary during scheduled maintenance visits. The **Main Menu** contains all fields that are accessible to users. They provide information on component failures, measurement parameters as well as editable fields and test procedures.

In general, editable parameters are displayed in bold font. Non-editable information is displayed in a thin font. Some parameters may become editable based on the state of the instrument (for example, the manual calibration mode and port can only be changed when the instrument is out of warm-up).

3.5.1 Quick Menu

The **Quick Menu** contains all the maintenance tools in one easy to use screen. It allows operators to perform calibrations, check important parameters and review the service history.

Span Calibrate

This field is used to perform a span calibration and should be only used when a known concentration of span gas is running through the measurement cell.

After activating the span calibrate field, a window will open with editable numbers. Change the numbers to match the concentration that the instrument is reading and select “accept”. The instrument span calibration has now been performed.

Event Log

This field enters a screen with a log of all the events that the instrument performs. These events include calibrations, errors, backgrounds and warnings. This log is stored on the removable USB flash memory.

Instrument

This field allows the instrument to be set to either “Online” (Normal instrument operation) or “In Maintenance” (data is not valid, as service work etc is being performed). This field is used to change the instrument into “In Maintenance” when service work is being performed.

Safely Remove USB

Before removing the USB memory stick, always select this menu item. (also occurs in the service menu 3.5.13). Failure to do this may cause corruption to the data on the memory stick.

Gain

This is a multiplication factor which is used to adjust the concentration measurement to the appropriate level (set by the calibration procedure). It is recommended that this value is recoreded in the station log book after each calibration.

Service Due

A field that notifies the user when the next instrument service is due. This value is editable in the “Next Service Due” field of the **Service Menu** (refer to Section 3.5.13). This field is only displayed in the 2 weeks prior to the date displayed in this field, or after the date has occurred.

3.5.2 Main Menu

There are six menus on the **Main Menu** screen.

Analyser State	See section 3.5.3.
General Settings	See section 3.5.8.
Measurement Settings	See section 3.5.9.
Calibration Menu	See section 3.5.11.
Service Menu	See section 3.5.13.
Communications Menu	See section 3.5.19.

Figure 8 – Main menu screen

3.5.3 Analyser State

This displays the status of various parameters that affect instrument measurement and various functions.

Status	See section 3.5.4.
Temperatures	See section 3.5.5.
Pressures & Flow	See section 3.5.6.
Voltages	See section 3.5.7.
Event Log	This field enters a screen with a log of all the events that the instrument performs. These events include calibrations, errors, background measurements, warnings. This log is stored on the removable USB flash memory.
Firmware Version	This field displays the firmware version currently in use on this analyser. This can be important when performing diagnostics and reporting back to the manufacturer.
Instrument	This field displays the instrument model number.
Board Revision	This field displays the PCB board version.
Power Failure	This field displays the time and date of the last power failure or when power was disconnected from the analyser.

3.5.4 Status

The **Status Menu** presents a list of the current "Pass/Fail" status of the main components. During start-up, the status of some parameters will be a dashed line.

Flow Block Temp (optional internal pump only)	If you have the optional internal pump this temperature must be within 10% of the heater set point (refer to Section 3.5.5) to keep a constant and accurate flow.
Sample Flow	Indicates whether the instrument has sample flowing through it.
A/D Input	A reference voltage is sent to the analog to digital input chip, this field will display a pass or fail indicating if the board is working.
Chassis Temperature	Displays whether the chassis temperature is within the acceptable limits.
Lamp Heater Temperature	Displays whether the Lamp heater temperature is within 10% of the heater set point (refer to Section 3.5.5).
Ref Voltage	Checks that the reference voltage is performing within acceptable limits 1.5V-4.5V Pass/Fail.
Lamp/Source	Checks if the lamp current is between 8-12 mA. Pass if within these limits, Fail if outside these limits.
USB Memory Stick	Detects whether a USB memory stick is plugged into the front USB port.

3.5.5 Temperatures

Temperature control and reporting.

Temperature Units	Editable field to allow the user to change the current temperature units of the analyser (Celsius, Fahrenheit, or Kelvin).
Set Point (LAMP)	Editable field that sets the target temperature that some heated components are regulated to.
Lamp	Displays current temperature of the lamp.
Flow block (optional internal pump only)	If an internal pump is installed, this field displays the current temperature of the flow block.
Chassis	Displays the temperature of air inside the chassis, measured on the main controller board.

3.5.6 Pressures and Flow

Pressure control and reporting display.

Note: If your instrument contains an internal pump, see section 8.3.2 for additions to this menu.

Pressure Units	Select the units that the pressure will be displayed in (torr, PSI, mBar, ATM, kPa).
Ambient	Current ambient pressure (outside the analyser).
Cell	Current pressure within the optical reaction cell.
Sample Flow	Indicates the gas flow through the sample port of the instrument, should be around 0.50 (±2%).

Note: The sample flow will read 0.00 if the flow transducer detects that flow has stopped.

3.5.7 Voltages

Voltage reporting display.

Conc Voltage (RAW)	Voltage from the preprocessor proportional to the detected gas signal from the reaction cell. This voltage represents the actual measurement of gas.
Ref. Voltage	Reference voltage as measured by the preamplifier board. This voltage is indicative of the UV lamp signal intensity.
Analog Supply	+12 volt (primary) power supply.
Digital Supply	+5 volt microprocessor power supply.
-10V Supply	-10 volt reading from the main controller board.

3.5.8 General Settings

Decimal Places	Select the amount of decimal places (0-5) used for concentration on the front screen.
Concentration Units	Sets the concentration units. (ppm, ppb, ppt, mg/m^3,µg/m^3, ng/m^3).
Conversion Factor	This option only appears if concentration units are set to gravimetric. You can select either 0°C, 20°C or 25°C.

Temperature Units	Select the units that temperature will be displayed in Celsius, Fahrenheit, or Kelvin.
Pressure Units	Select the units that the pressure will be displayed in (torr, PSI, mBar, ATM, kPa).
Date	Displays the current date and allows users to edit if required.
Time	Displays the current time and allows users to edit if required.
Backlight	Select how long the instrument backlight will stay on for either seconds (30), minutes (1, 2, 5, 10, 30), hours (1), or always on/always off.
Front Screen	This field allows the user to display concentrations on the front screen in two formats; the first is "Inst. only" which displays only the instantaneous concentration reading, the second is "Inst & Avg" which displays both instantaneous and average concentration on the front screen. The average is measured over the time period set in Measurement Settings (refer to Section 3.5.9)
Char 0 has Slash	When enabled, the instrument will display the zero character with a slash (ø) to differentiate it from a capital 'O'.

3.5.9 Measurement Settings

Average Period	Set the time period over which the average will be calculated: Minutes (1, 3, 5, 10, 15, or 30) or Hours (1, 4, 8, 12, or 24).
Filter Type	Sets the type of digital filter used (None, Kalman, 10 sec, 30 sec, 60 sec, 90 sec or 300 sec). **Note:** The Kalman filter is the factory default setting and must be used when using the instrument as a U.S. EPA equivalent method. The Kalman filter gives the best overall performance for this instrument.
Noise	The standard deviation of the concentration. The calculation is as follows: ▪ Take a concentration value once every two minutes. ▪ Store 25 of these samples in a first in, last out buffer. ▪ Every two minutes, calculate the standard deviation of the current 25 samples. This is a microprocessor-generated field and cannot be set by the operator. **Note:** This reading is only valid if zero air or a steady concentration of span gas has been fed to the analyser for at least one hour.

3.5.10 Calibration Menu

Calibrating the instrument should be done with care. Refer to section 5 before using these menus.

Note: If your instrument contains an internal pump, see section 8.3 for additions to this menu.

Calibration Type	Select the "Calibration Type" field and select either "Timed" or "Manual". Timed calibration is an automatic calibration controlled by the; Interval between cycles. Length of each calibration cycle. When the calibrations will begin. Whether the calibration will perform automatic compensation. Manual calibration will perform a manual calibration depending on the calibration mode selected below. **Note:** Timed calibration with span compensation enabled does not fulfil U.S. EPA or EN approval.
Calibration Mode	Displays the current mode the analyser is set to.
Calibration Port	This is only accessible once the instrument has completed warm-up. Select whether the instrument will sample from the external span/zero source (Calibration port) or from the optional internal span/zero source (IZS).
Cycle Time	Displays the current calibration cycle time set in the **Calibration Menu**.
Span Calibrate	This field is used to correct the span calibration setting and should be used only when a known concentration of span gas is running through the measurement cell. When this is happening activate the span calibrate field, a window will open with editable numbers, change the numbers to the concentration that the instrument is receiving and select accept. The instrument span calibration has now been set.

Zero Calibrate	This field is used to correct the zero calibration setting. This option should be used only when zero gas is running through the measurement cell. When this is happening activate the zero calibrate field, a window will open with editable numbers, leave the numbers at 0000.000 and select accept.
Pressure Calibration	This field allows the user to calibrate the pressure sensors as explained in section 5.8.
Calibration Pressure	This field displays the measured manifold pressure during the last calibration.
Calibration Temperature	Temperature at which the instrument performed its last span calibration.

3.5.11 Manual Mode

Calibration Mode **(Only accessible once instrument has completed warm-up)**	When in manual mode the instrument's operational mode can be chosen from the following: **Measure:** the normal measurement through the sample port. **Zero:** takes air through the calibration port so that a zero calibration can be performed. **Span**: takes air through the calibration port so that a span calibration can be performed. **Cycle:** performs a zero, then a span then returns to measure mode. The length of time spent measuring calibration gases is set in Cycle Time (below).
Calibration Port **(Only accessible once instrument has completed warm-up)**	Select whether the instrument will sample from the external span/zero source (Calibration port) or from the optional internal span/zero source (IZS).
Cycle Time	The time period that the zero and span calibrations will last in "Cycle". Users can set the time from (5 to 59 minutes).

3.5.12 Timed Mode

Date	Enter the date for the next calibration to start.
Time	Enter the time that calibration will be performed. The time is set using a 24 hour clock.
Repeat	The calibration will be automatically run again after the specified amount of time. This field specifies the delay period (from 1 to 20,000 units, as specified below).

Units	This is the units of the repeat delay period. Thus, a repeat of 3 and units of days means that a calibration will automatically be performed every 3 days.
Span Compensation	When "Enabled" the instrument will adjust the gain based on the span level, when set to "Disabled" no calculation is made. **Note:** Timed calibration with span compensation enabled does not fulfil both U.S. EPA approval and EN certification.
Span Level	Enter the concentration of span gas used during the timed span calibrations.
Cycle Time	Is the time period that the span calibration will last. The user can set the time (1 to 59 minutes).

3.5.13 Service

The **Service Menu** displays diagnostic information. The settings return to the previously set conditions when the operator leaves this menu.

Diagnostics	See section 3.5.14
Calculation Factors	See section 3.5.18
Save Configuration	Saves all of the EEPROM-stored user-selectable instrument configurations to the USB memory stick (calibration and communication settings, units, instrument gain etc). If you have problems with your instrument use this function to save settings to the removable USB stick and send this file (and the parameter list) to your supplier with your service enquiry.
Save Parameter List	Saves a text file of various parameters and calculation factors. If you have problems with your instrument use this function to save settings to the removable USB stick and send this file (and the configuration) to your supplier with your service enquiry.
Load Configuration	Loads a configuration file from the USB memory stick. Thus, you can save a configuration and restore it later.
Auto-Backup	Selects whether the parameter and configuration files are automatically saved once a day (at midnight).
Load Auto-Backup Configuration	Loads the auto-backup configuration file. This is useful when the configuration has been changed in error.

Instrument	This field allows the instrument to be set to either "Online" (Normal instrument operation) or "In Maintenance" (data is not valid, as service work etc is being performed).
Next Service Due	User editable field to set the date when the next instrument service is required. Section 6 has a recommended maintenance schedule that may be used as a basis for the interval entered above. This value is also displayed as a non-editable field in the **Quick Menu**.
Safely Remove USB Stick	This feature must be activated to safely remove the USB stick (also found in the **Quick Menu**).
System Restart	Activating this will reboot the microprocessor.

3.5.14 Diagnostics

The **Diagnostics Menu** allows the user to gain a greater insight into what the instrument is doing.

Digital Pots	See section 3.5.15
Valves Menu	See section 3.5.14
Tests	See section 3.5.17
Pressure/Temperature/Flow Comp	Set to either "On" or "Off". • "On" is used to compensate analyser measurements for environmental fluctuations that might affect readings (pressure, temperature and flow). • "Off" is used only when running diagnostics to see fluctuations in readings.
Diagnostics Mode	The instrument can be placed in 4 diagnostic modes: • **Operate** which leaves the instrument in normal operation mode. • **Optic** which configures the instrument for tests on the optical measurement source. • **Electrical** which configures the instrument for testing of the electrical circuits. • **Preamp** which configures the instrument for testing of the pre-amplification circuitry.
Control Loop	When "Enabled" the instrument will control all processes within the instrument. Selecting "Disabled" will pause the instrument control over certain processes and parameters (e.g. digital pots). The user can now manually alter and adjust digital pots without the microprocessor overwriting their changes. **Note:** Turning off the control loop will disrupt normal data logging.

3.5.15 Digital Pots

Pots are electronically controlled digital potentiometers used for adjustments to operations of the analyser. This menu should be accessed only during diagnostics.

Unless the control loop is turned off (refer to Section 3.5.14), changes to the pots will be modified by the microprocessor. This is intentional; some diagnostics are best done with instrument feedback, and some are best done with the instrument inactive.

Lamp Adjust	(100-200)	Adjusts the UV lamp current.
Lamp current	(9.5-10.5)	Displays the UV lamp current.
PGA Gain	(1-128)	Displays gain of the ADC for the measurement cell.
Input Pot	(10-200)	Input gain.
Conc Voltage (RAW)	(0-3.0)	The voltage measured by the analog to digital converter
Conc Voltage	(0-3)	The voltage after adjustment by the PGA gain factor.
Meas. Zero (COARSE)	(50-200)	This pot maintains the electronic zero adjustment.
Meas. Zero (FINE)	(1-255)	This pot maintains the electronic zero adjustment.
Ref. Voltage	(1.5-4)	The reference voltage of the detector.
Test Pot	(0)	This pot is for diagnostics only.

3.5.16 Valve Menu

The **Valve Menu** allows the user to observe the opening and closing of valves as well as the ability to open and close them manually.

Valve Sequencing	When “Enabled” the instruments valves will open and close under microprocessor control. When “Disabled” the valves will change only in response to manual controls. Manually changing a valve while sequencing is enabled does not prevent the microprocessor from changing it again. Valve sequencing will remain off unless the instrument has returned to main screen for longer than 2 minutes.
Span/Zero Select	Shows the action of the valve that determines whether sample gas or calibration gas/internal zero air is being sampled (Open = Span/Zero, Closed = Sample gas).
Reference Select	When “Closed”, the instrument feeds directly into the measurement cell; when “Open,” the instrument feeds through the Ozone scrubber before filling the measurement cell.
Pressurised Zero (optional)	When “Closed”, the Aux-In port is blocked; when “Open,” the Aux-In port is open (refer to Section 8.4).

3.5.17 Tests

Screen Test	Performs a screen test by drawing lines and images on the screen so that the operator can determine if there are any faults in the screen. Press the left or right key to step through the test. The up and down arrow keys will adjust the contrast.
Digital Inputs	Displays the status of the 0-7 digital input pins. Value will be a 0 or a 1.
Digital Outputs	This menu item allows the user to view the pins that digital outputs are located on. The output can be switched on and off to test the connection. **Note:** Entering either the **Digital Inputs** or **Digital Outputs Menu** will temporarily disable all digital and analog input/outputs. This will affect logging via these outputs. Exiting the menu restores automatic control.

3.5.18 Calculation Factors

The calculation factors provide the values used to calculate different aspects of measurement and calibration. The following fields are found in one, two or all of these sections and only the pressure, temperature, flow (PTF) correction fields are non-editable.

Instrument Gain	A multiplication factor used to adjust the concentration measurement to the appropriate level (set at calibration).
Zero Offset	This field displays the offset created from a zero calibration. This is the concentration measured from zero air and is subtracted from all readings.
Background	The correction factor calculated from the background cycle (used to eliminate background interferences).
PTF Correction	Displays the correction factor applied to the concentration measurement. This correction is for changes in pressure, temperature and flow.

3.5.19 Communications Menu

Configures how the instrument communicates with external instrumentation and data loggers.

Data Logging Menu	See section 3.5.20
Serial Communications	See section 3.5.21
Analog Input Menu	See section 3.5.22
Analog Output Menu	See section 3.5.23
Digital Input Menu	See section 3.5.24
Digital Output Menu	See section 3.5.25
Network Adaptor Menu	See section 3.5.26
Bluetooth Menu	See section 3.5.27

3.5.20 Data Logging Menu

Data Log Set-up – Numeric	This allows up to 12 parameters to be logged. After each parameter (labelled "Logging Param. 1" – "Logging Param. 12") place the number of the parameter that is to be logged. A 255 indicates the end of the list of parameters to be logged.
Data Log Set-up – Test	This is an alternate and easier way to select logged parameters. Instead of entering a number, select the item by name from a list Select the blank line to indicate the end of the list of parameters to be logged.
Data Log Interval	Set the interval that measurement data will be logged at. (1 second to 24 hours) or Disabled which means that no data is logged by the USB memory stick. **Note:** It takes about 1/3 of a second to log a measurement, selecting the 1 second interval may slow down serial communications.
+/- Keys	The list of parameters must be contiguous. Thus, when you delete a logging parameter, any parameters below it will be moved up. The '–' key will also delete the currently highlighted parameter; the '+' key will insert a new parameter at that location, moving the others down.

3.5.21 Serial Communications

Multidrop ID	This is the ID of the analyser when Multidrop RS232 communications is used. This defaults to 40 but can be changed if multiple Serinus instruments are on the same RS232 cable.
Delay (RS232#2)	When set to "enabled" it will delay the serial communication through the RS232 #2 port by approximately 0.25 seconds. This is used in systems that cannot cope with the rapid response of the Serinus instruments. When set to "Disabled" communication will proceed without delay.
Baud (RS232 #1)	Sets the baud rate for this serial channel (1200, 2400, 4800, 9600, 14400, 19200, or 38400).
Protocol (RS232 #1)	Sets the protocol used for this serial channel (EC9800, Bavarian, Advanced, or Modbus).
Baud (RS232 #2)	Sets the Baud rate for this serial channel (1200, 2400, 4800, 9600, 14400, 19200, or 38400).
Protocol (RS232 #2)	Sets the protocol used for this serial channel (EC9800, Bavarian, Advanced, or Modbus).

3.5.22 Analog Input Menu

The Serinus supports 3 analog inputs from the 25 pin I/O connector. Each input is a 0 to 5 volt input that can be scaled and then logged to the internal memory, or accessed remotely as parameters 199-201.

Input 1/2/3 Multiplier	The input voltage will be multiplied by this number. Eg if a sensor has a 0-5V output for a temperature of -40°C to 60°C, then the multiplier would be (60-(-40))/5 = 20.
Input 1/2/3 Offset	The value will be added to this input. Continuing the example in the multiplier description, the offset should be set to -40, so that a voltage of 0V, will be recorded as -40°C.
Input 1/2/3 Reading	The current reading from the input voltage, after the multiplier and offset have been applied. This is the value that would currently be logged, or reported as parameter 199-201 via USB or serial requests.

3.5.23 Analog Output Menu

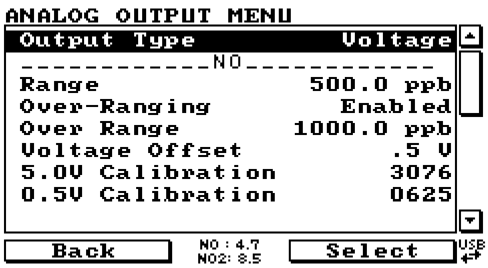

Figure 9 – Analog output menu – voltage

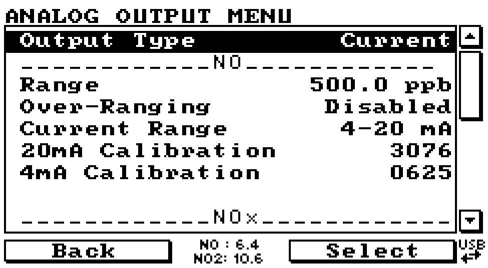

Figure 10 – Analog output menu – current

Output Type	The output can be set to be either current or voltage. Only some of the fields below will be displayed depending on which analog output type is selected.
Range	Set upper range limit (in concentration units) to desired concentration. This value cannot exceed the “Over Range” value.
Over-Ranging	Set to “Enabled” or “Disabled” to turn the over-ranging feature on or off.
Over-Range	This field is only visible when Over-ranging is set to “Enabled”. Set to the desired over range value. This value cannot be set below the RANGE value. This is the alternate scale the recorder or DAS indicates when over-ranging is active and enabled. (When 90% of the set range is reached, this auto range is effective. When 80% of the original range is reached, it returns to the original range).
Voltage Offset	Choices are 0V, 0.25V, and 0.5V. Recorder or data logger output will reflect this.
5.0V Calibration	Enables the user to calibrate the analog output at a full scale point.

0.5V Calibration	Enables the user to calibrate the analog output at a low point.
Current Range	Enables the user to set desired current ranges. Choices are 0-20mA, 2-20mA or 4-20mA.
20mA Calibration	Enables the user to calibrate the current output at a full scale point of 20mA
4mA Calibration	Enables the user to calibrate the current output at a low point.

3.5.24 Digital Inputs Menu

This menu is used to remotely trigger zero and span calibrations. This is done by assigning the 8 digital inputs with one of the following commands.

Disabled: No action taken

Do Span: Perform a span check

Do Zero: Perform a zero check

The input is triggered with an active low. The actual digital input pin-outs are listed in the menu.

Example

Here is an example for a typical configuration between an analyser and either a data logger or calibrator (master device):

1. Set the jumper JP1 to 5V position.
2. Connect one of the master devices digital output signal to pin 18 and the ground signal to pin 5 of the analysers analog/digital 25 pin female connector.
3. Program master device to output 0 volts to pin 18 when a span is desired.
4. In the analyser's digital input menu assign DI 0 Do Span. The same procedure can be followed to also activate zero calibrations.
5. Pin 6 of the analysers analog/digital 25 pin female connector can be connected to one of the other master devices digital outputs and the analyser can be set so DI 1 is assigned to "Do Zero".

3.5.25 Digital Outputs Menu

This allows the analyser to trigger external alarms in response to certain events.

There are 8 different pins available, which will be set high during an associated event:

- Disabled (never triggered).
- Power Supply Failure.
- Ref Voltage Failure.
- A2D Failure.
- Lamp Failure.
- Flow Heater Failure.
- Lamp Heater Failure.
- Chassis Temp Failure.
- USB Disconnected.
- Background.
- Span.
- Zero.
- System.

Assign the digital outputs 0-7.

3.5.26 Network Adaptor Menu

The **Network Adaptor Menu** allows the user to view or set the I.P. address, Netmask and Gateway if the optional network port is installed.

To read the IP address, perform the following steps:

1. Set the instrument to Read IP.
2. Manually cycle power off
3. Wait 3 seconds.
4. Turn power on.
5. Read or set the IP address.

Start-up Mode	The following modes are available:
Normal	In this mode nothing is done with the network port during boot-up. It is assumed to be configured correctly or unused.
Read IP	This mode interrogates the network port for its IP address. The menu will display this address after boot-up.
Set IP	You may enter an IP address, Netmask, and Gateway address (following the usual rules for formatting these addresses). Please note that at this time the Serinus does not validate the correctness of these entries. When you cycle power, the Serinus will first instruct the network port on its new address. It will then switch to Read IP mode and read back the address it just set so that you may verify it in the menu.
Set DHCP	This sets the network port into DHCP mode, effectively setting its IP address to 0 and allowing the network to assign the Serinus an IP address.

3.5.27 Bluetooth Menu

Serinus instruments manufactured after 2012 support Bluetooth communication through the “Serinus Remote” Android Application (refer to Section 4.6).

Bluetooth	This field indicates whether the analyser is remotely connected to an Android device.
Reset Bluetooth	After changing the ID or PIN. Reboot the Bluetooth module. This is done by resetting the instrument or by using this menu item to reboot only the Bluetooth.
ID	This is the Bluetooth ID of the analyser. In edit mode the number keys act like a telephone keypad. Every time a number key is pressed, it cycles through its choices. The up/down arrow keys scroll through all the numbers and the entire alphabet. 1 = 1 or space 2 = 2, A, B, C, a, b, c 3 = 3, D, E, F, d, e, f 4 = 4, G, H, I, g, h, i 5 = 5, J, K, L, j, k, l 6 = 6, M, N, O, m, n, o 7 = 7, P, Q, R, S, p, q, r, s 8 = 8, T, U, V, t, u, v 9 = 9, W, X, Y, Z, w, x, y, z 0 = 0 or space The default setting is the Serinus ID/Serial Number. Note that the word “Serinus” is always the first part of the name and cannot be edited.
PIN	This is a passcode/pin required for the “Serinus Remote” application to connect to the analyser. The default pin is 1234.

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4. Communications

The Serinus can perform communication through 5 different paths; RS232, USB, 25 pin digital/analog input/output, TCP/IP network (optional) or Bluetooth. The "Serinus Downloader" application allows data downloads and remote activation from a PC.

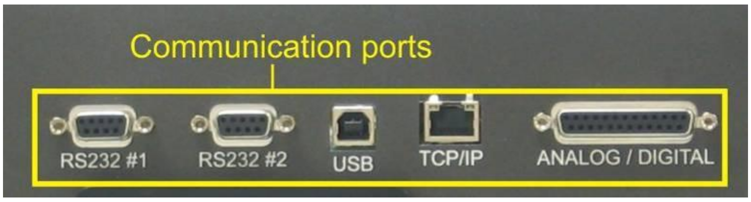


Figure 11 - Communication ports

4.1 RS232 Communication

RS232 communication is the most versatile way to access data from the instrument. Port #1 directly interfaces with the RS232 port. Port #2 supports multi-drop. This is a configuration of multiple analysers connected via the same RS232 cable. Verify that the "Multidrop ID" is set to either 0 (for direct connection) or a unique value which is different to the other analysers in the chain (refer to Section 3.5.21).

The Serinus supports the following protocols:

- Advanced protocol (Appendix A)
- EC9800 protocol (Appendix B)
- Bavarian protocol (Appendix C)
- ModBus protocol (Appendix D)

4.2 USB Communication

This port is a faster version of the RS232 serial port, which uses a USB connection.

It supports the following protocol:

- Advanced protocol (Advanced Protocol Parameter List)

4.3 TCP/IP Network Communication (optional)

This port is best used for remote access and real-time access to instruments when network connectivity is available.

It supports the following protocol:

- Advanced protocol (Advanced Protocol Parameter List)
- Configuring the network port requires setting the IP address. This is done via the **Network Adaptor Menu** (refer to Section 3.5.26).

4.4 Digital/Analog Communication

The 25 Pin Analog/Digital port on the rear of the analyser sends and receives analog/digital signals to other devices. These signals are commonly used to activate gas calibrators or for warning alarms.

Analog Outputs

The analyser is equipped with three analog outputs that can be set to provide either voltage (0-5V) or current (0-20, 2-20, 4-20 mA). The analog outputs are tied to the instrument measurements:

Table 1 – Analog outputs

Analyser	Output 1	Output 2	Output 3
S10	O_3	N/A	N/A
S30	CO	N/A	N/A
S40	NO	NO_2	NO_X
S44	NO	NH_3	NO_X
S50	SO_2	N/A	N/A
S51	SO_2	H_2S	N/A
S55	H_2S	N/A	N/A
S56	TS	N/A	N/A
S57	TRS	N/A	N/A

Analog Output Calibration Procedure

1. Connect a volt meter (using an appropriate adaptor or probes on the volt meter) to the ground (pin 24) and the relevant output pin (pin 10).
2. Navigate to the “**Communications**” →**Analogue Output Menu.**
3. Adjust the “0.5V Calibration” value until the volt meter reads 0.500 +/ .002.
4. Adjust the “5.0V Calibration” value until the volt meter reads 5.00 +/ .002.

Analog Inputs

The analyser is also equipped with three analog inputs with resolution of 15 bits plus polarity, accepting a voltage between 0-5 V.

Digital Status Inputs

The analyser is equipped with 8 logic level inputs for the external control of the analyser such as “Zero/Span” sequences. Each input has a terminating resistor which can be either PULL UP or PULL DOWN. This is set using the Jumper JP1 on the back panel printed circuit board (refer to Section 3.5.24).

Digital Status Outputs

The analyser is equipped with 8 open collector outputs which will convey instrument status condition warning alarms such as no flow, sample mode, etc. Two of the digital outputs can be set so that there is +5V or +12V available on the 25 pin connector for control purposes.

In the default jumper locations these two outputs will function normally as open collector outputs. If moved to the position closer to the 25 pin connector then DO 0 will supply +12V and DO 1 will supply +5V. These supplies are limited to about 100mA (refer to Section 3.5.25).

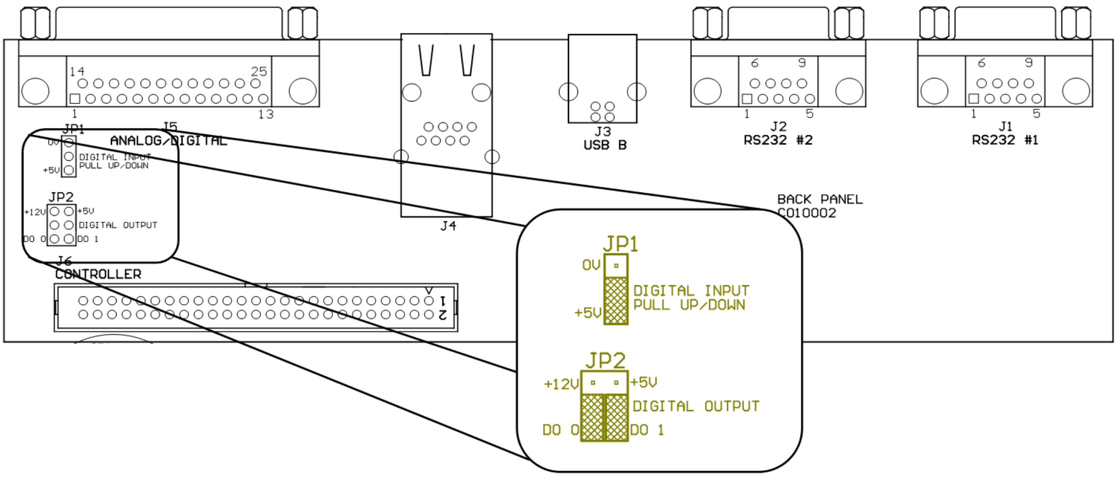


Figure 12 – Serinus 25-pin microprocessor board (with default jumpers highlighted)

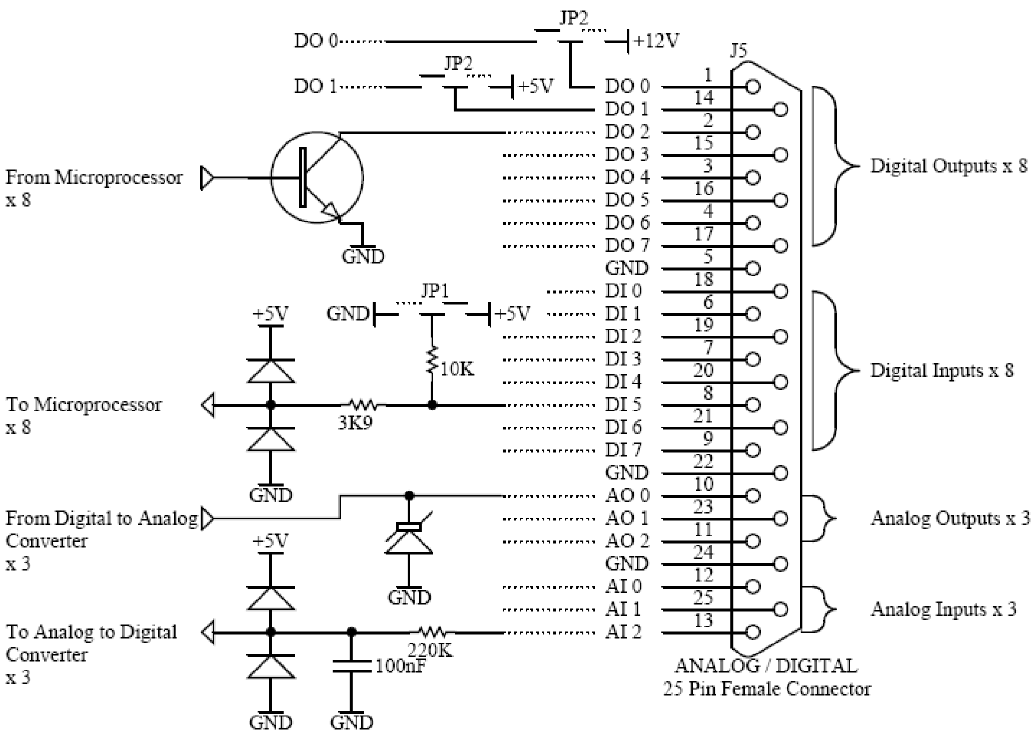


Figure 13 - External 25pin I/O individual pin descriptions

CAUTION
The analog and digital inputs and outputs are rated to CAT I (Voltage should not exceed 12VDC). Exceeding these voltages can permanently damage the instruments and void the warranty.

4.5 Serinus Downloader Program

The Serinus Downloader program is designed to allow the operator to acquire data directly from the analyser and control it remotely. The Serinus downloader program has four main windows:

- Settings: configurations are made to communicate with the analyser.
- Data: data is downloaded into a spread sheet format.
- Remote Screen: Allows the analyser to be controlled remotely.
- Remote Terminal: a diagnostic tool used to check instrument operation and parameter values.

4.5.1 Settings

Within this window both the data format setting and analyser communications settings are defined. There are two icons in the main header. They are “Save Settings” (which saves the current settings as default) and “Cancel changes”.

Output File

Type in the destination (folder) including file name (extension must be .txt).

Date Format

Type in the date format that data will be written (within the text file).

The format must be as specified; that is, 4 digits of year, 2 of month, 2 of day, 2 of hour, and 2 of minutes. The year digits are separated by slashes, the date and time fields are separated by a blank, and the hour and minute fields are separated by a colon.

The output data can be stored in one of three ways:

- Append Data: Add data onto the end of the current entries within the text file.
- Overwrite Data: Always create new text file rather than adding to an existing file.
- Prompt User: Displays a window that prompts user to overwrite data. If ”No” is selected data will be appended to the current file.

Connection Type

Choose the connection to the analyser:

- Direct Serial Connection: The analyser is connected to the PC via a serial cable.
- Network Connection: The analyser is connected via a network.
- USB Connection: The analyser is connected directly to PC via a USB cable.

Port

The contents of this field depend on which connection you have made:

- Direct Serial Connection: Select a COM port.
- Network Connection: Enter the port number of the analyser (32785).

Baud

For a direct serial connection, this specifies the baud rate of the analyser (refer to Section 3.5.21).

IP Address

For a network connection, this specifies the IP address of the analyser (refer to Section 3.5.26).

Analyser

With a USB connection, the drop down list will display all of the connected analysers.

Analyser ID

For a multi-dropped direct serial connection you must supply the multidrop ID of the specific analyser (refer to Section3.5.21). If only one analyser is connected, this field can remain 0.

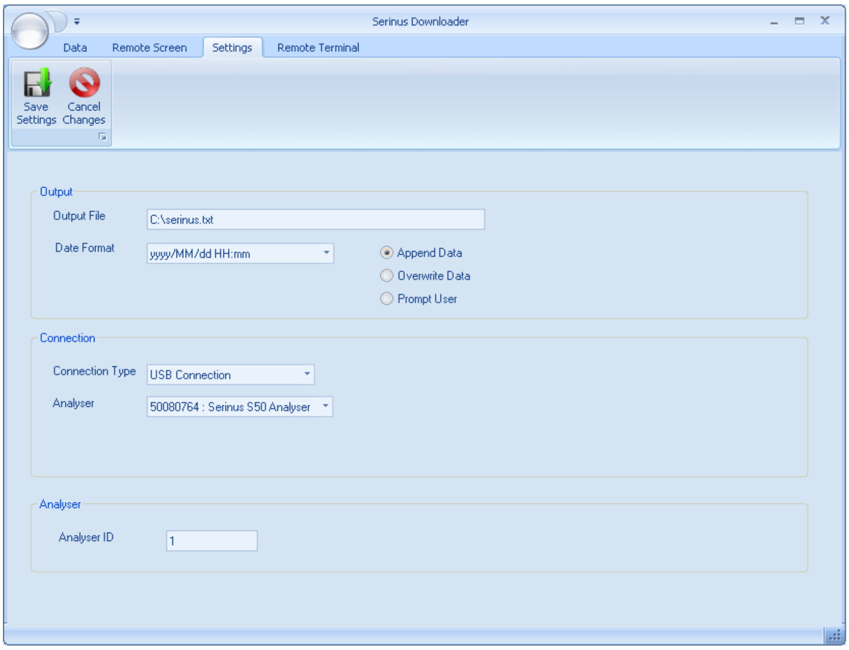


Figure 14 - Serinus downloader - settings tab

4.5.2 Data

The data window presents a spread sheet with rows (numeric) and columns (labelled as per parameter). Refer to Figure 15.

State Date/End Date

Specify the start and end time of the requested download. All data logged between these two times will be downloaded and displayed.

Acquire Data

Download the specified data.

Save Data

Save the downloaded data to a text file in Excel format.

Clear Data

Erase the downloaded data, allowing you to download a different set of data.

Rebuild Index

This function is obsolete and no longer used.

Reset Memory Stick

This function is obsolete and no longer used.

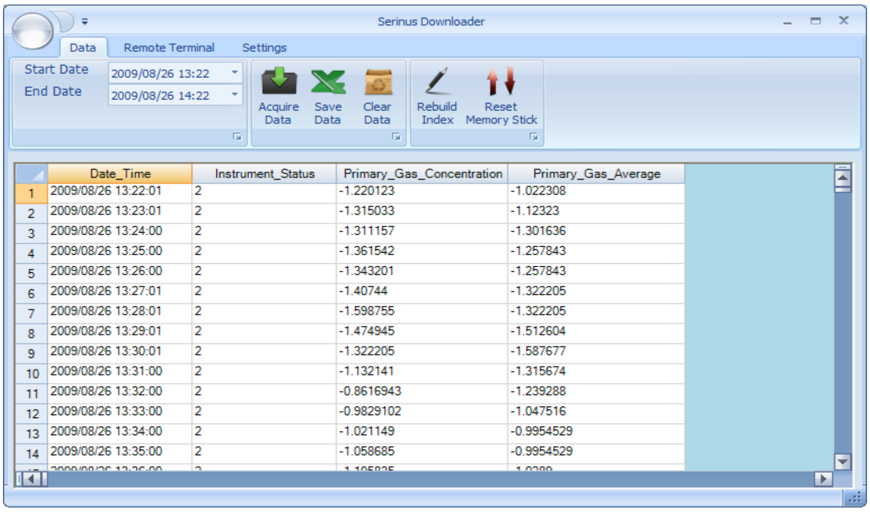


Figure 15 - Serinus downloader – data tab

4.5.3 Remote Screen

The remote screen tab allows the user to connect to the Serinus instrument and control it remotely.

If connecting via a serial cable, the Serinus must be in "Advanced" protocol for that serial port. Refer to Figure 16 - Serinus downloader – remote screen tab.

Connect

Connects to a Serinus and updates the display. The screen is not "live", it must be updated after every action. When you initiate an action (such as pressing a button) the screen will automatically update. However, if the Serinus changes state (such as changing the displayed concentration on the instrument screen), this change will not automatically appear on the Serinus downloader display. Use the "Refresh Screen" button to update the Serinus display without sending a keystroke.

Disconnect

Disconnects from the Serinus. This happens automatically if you exit the program. If you want to connect to a different Serinus, you will need to disconnect before you change the Settings tab.

Refresh Screen

Updates the downloader's display with the most recent screen from the Serinus.

Display

The display area shows the screen as it appears on the Serinus. To navigate through the menus, click the left or right buttons on the screen, or use the escape and enter keys on the computer keyboard.

To scroll up or down, use the arrow cursor keys on the computer keyboard (the buttons on the display do not function).

To enter values, click on the keypad next to the display or use the number keys on the computer keyboard.

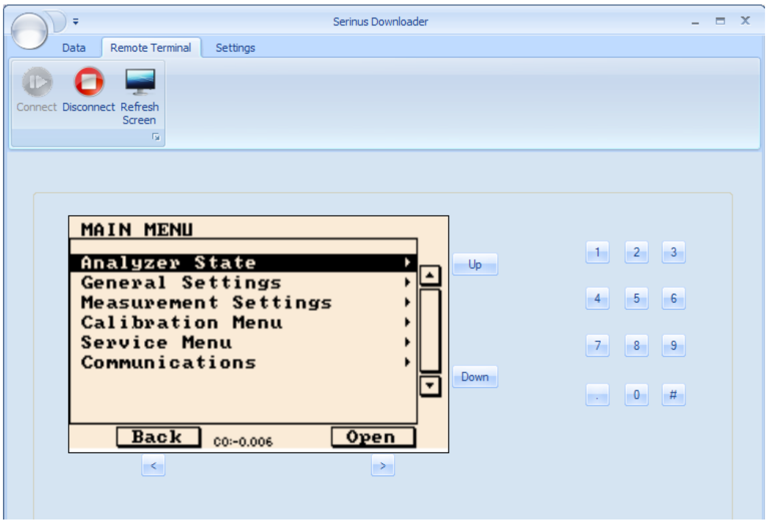


Figure 16 - Serinus downloader – remote screen tab

4.5.4 Remote Terminal

The remote terminal tab is a diagnostic tool used to check instrument operation and parameters. The remote terminal is used in a similar way to "ping" a computer to ensure communications are working properly. Firstly the downloader program must be connected to the instrument and the green connect button in the top left hand corner must be clicked. Refer to . The remote terminal tab consists of 3 different sections:

Connect

Connects to the analyser. Note that this button will be greyed out and disabled if the downloader program is already connected via the remote screen.

Advanced Protocol

Assumes the Serinus is in advanced protocol. Enter a parameter number to retrieve and click "Get."

EC9800 Protocol

Assumes the Serinus is in EC9800 protocol and the program is connected via a serial cable. Enter an EC9800 protocol command and click "Send".

Received Data

Displays the received data. Values can be cleared by pressing the clear button.

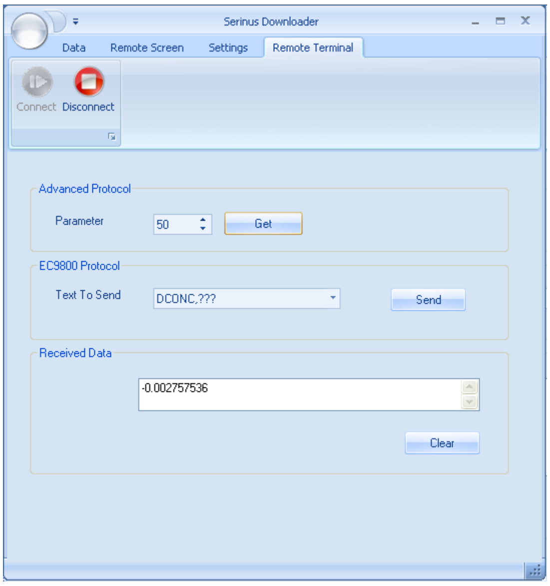


Figure 17 - Serinus downloader – remote terminal tab

4.6 Serinus Remote App/Bluetooth

Ecotech's Serinus Remote Application allows for any Android device (Tablet or Smartphone) to connect to an analyser.

Using the Serinus Remote Application the user can:

- Completely control the analyser using a remote screen displayed on the device.
- Download logged data and take snapshots of all the instrument parameters.
- Construct graphs from logged data or real time measurements.

4.6.1 Installation

The Serinus Remote app. can be found in the Google Play Store by searching for 'Ecotech' or 'Serinus'. Once found, choose "Install" the Application and "Open" to start the application.

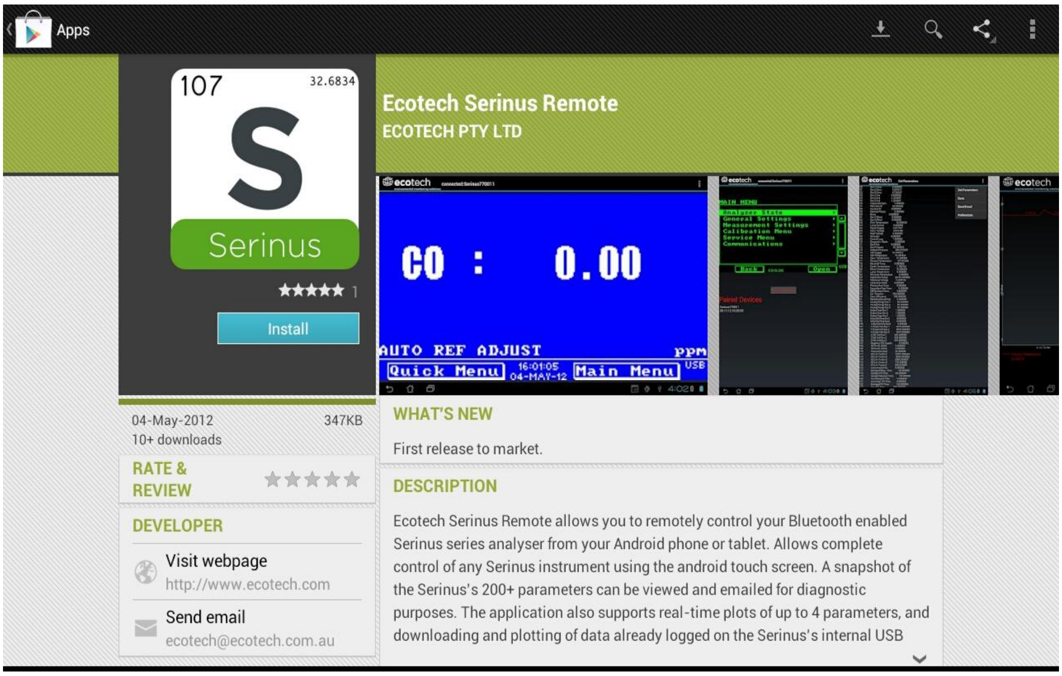


Figure 18 – Downloading the app from Google Play store

Note: A menu containing additional features and functions can be accessed by entering the **Options Menu** (or similar) on your device. The location and format of this menu may vary.

4.6.2 Connecting to the Analyser

Refer to the **Bluetooth Menu** to find the Serinus analyser Bluetooth ID and PIN (refer to Section3.5.27).

To connect to an analyser:

1. Touch the “Scan Serinus Analysers” button at the bottom of the screen.
2. Select the Analyser ID from either the “Paired Devices” or the “Other Available Devices” (see ID in the **Bluetooth Menu**).
3. Input the PIN (if prompted to do so) then press “Ok” (see PIN in the **Bluetooth Menu**).

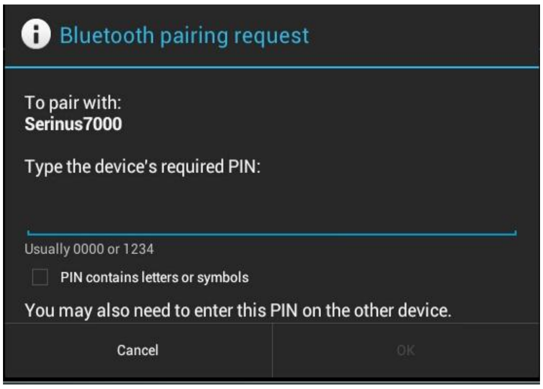


Figure 19 – Bluetooth pairing request

A screen shot of the analyser’s current screen should appear on your smartphone or tablet. To disconnect press the “Back” key/button on the device.

Note: Once the analyser has been paired with the device it will appear under “Paired Devices” and the PIN will not need to be entered in again in order to connect to the analyser.

4.6.3 Control Serinus Analyser

Once connected the user has full control of the analyser. The range for remote control depends on the device’s Bluetooth capabilities and any intervening obstructions, but is usually up to 30m.

Remote Screen Operation

With the exception of the number pad, all button functions/actions can be performed by touching the screen. This includes the selection buttons and the scroll buttons. Touching any part of the screen where there is not already a button also enacts the functions of the scroll buttons.

The “Back” button will return to the Selection screen, allowing you to connect to a different analyser.

- Main Screen: Touching the upper half of the screen increases the contrast and touching the lower half of the screen decreases contrast.

- Menus: Touching the upper or lower half of the screen allows the user to scroll up and down respectively.
- Left-hand section of the screen: Swiping from right to left brings up the number pad for entering numbers (swipe from left to right to hide the number pad).

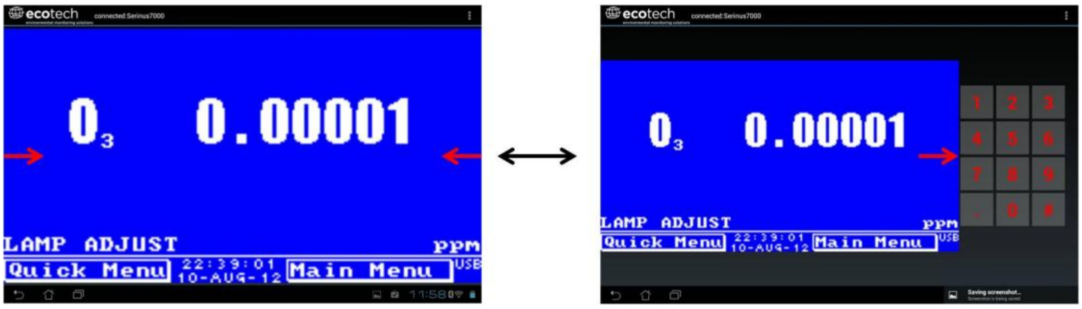


Figure 20 – Entering numbers into Serinus Application

- Right-hand section of the screen: Swiping from left to right brings up a list of available analysers (swipe from right to left to hide the analyser list).

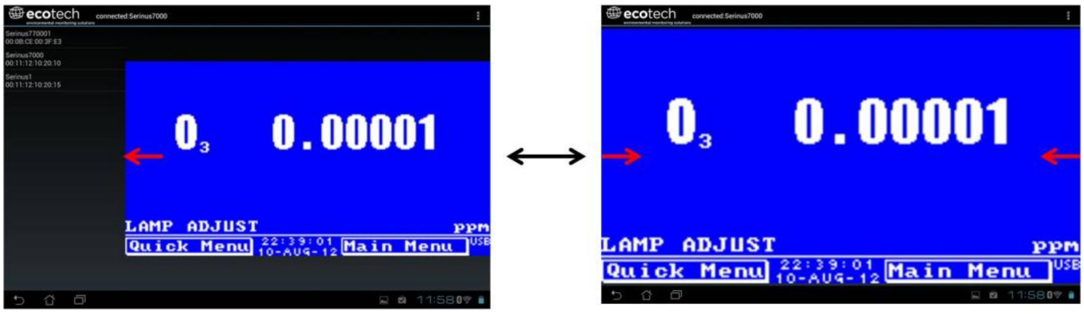


Figure 21 – Switching analysers in Serinus Application

Options Menu

The **Options Menu** is accessed by the grey button in the top right corner of the screen.

Refresh	Refresh the display.
Show/Hide NumPad	Show or hide the number pad.
Real-time Plot	Refer to section 4.6.4.
Download	Download data.
Get Parameters	Refer to section 4.6.5.
Preferences	Refer to section 4.6.6.

4.6.4 Real-time Plot

Allows user to view real-time plotting of selected parameter(s) and graph up to four parameters at the same time. The user can also scroll from left to right, top to bottom, or zoom in and out on the plot by swiping.

Once the plot is zoomed or scrolled, it enters into “Observer” mode, meaning that real-time updating is suspended. Press at the top of the screen to return to “Normal” mode, which will re-centre the plot and resume real-time updating.

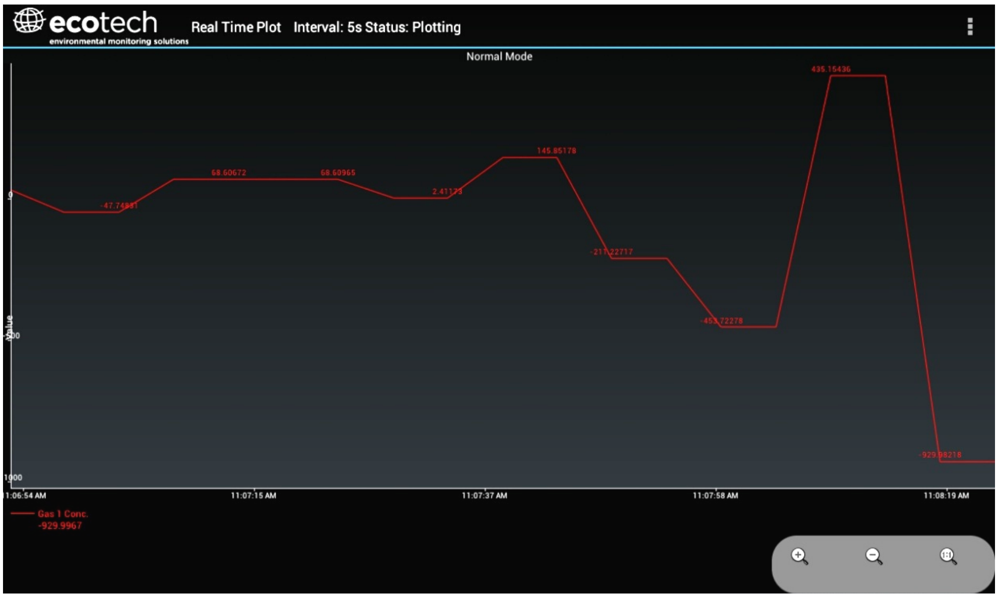


Figure 22 – Real-time plot

Options Menu

The **Options menu** is accessed by the grey button in the top right corner of the screen.

Start	Restarts graphing if it has been stopped and returns the graph to “Normal” mode.
Stop	Stops collecting data. In this mode you can scroll the display without going into “Observer” mode, because the system has no data collection to suspend. It is necessary to “Stop” data collection to set the interval.
Clear	Clears the window and restarts the graphing.
Save	Generates a filename from the current date and time, saves the parameter data in the location already specified in preferences, and then asks to send the saved text file as an attachment to an email.
Set Interval	While data collection is stopped, the user can specify the time intervals between collections.

4.6.5 Get Parameters

Downloads a list of parameters and corresponding values directly from the analyser.

Options Menu

Get Parameters	Refreshes the parameter list display.
Save	Generates a filename from the current date and time, saves the parameter data in the location already specified in Preferences, and then asks to send the saved text file as an attachment to an email.
Send E-Mail	Sends an email with the parameter data in the body of the email, formatted as displayed.
Preferences	See section 4.6.6.

4.6.6 Preferences

Preferences Menu allows the operator to adjust the directory settings, the logs, format and the colour scheme settings. It can be accessed through the **Options Menu** in most windows.

Directory Settings

The operator can specify/select where to save the parameter lists, logged data and real time plots.

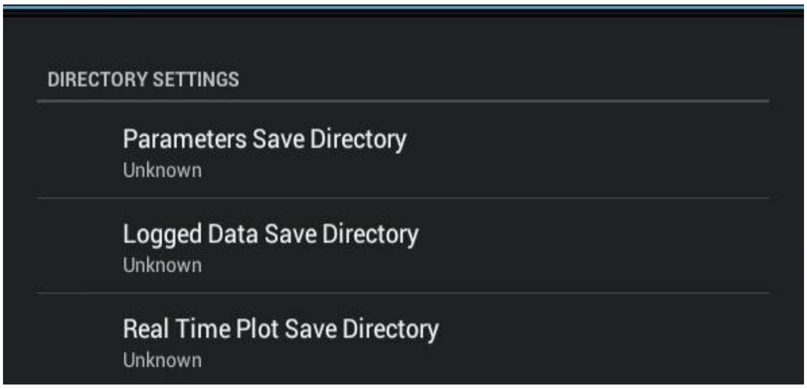


Figure 23 – Directory settings

Logs Format

When downloading logged data, the parameters can be displayed in one line or each in a separate line.

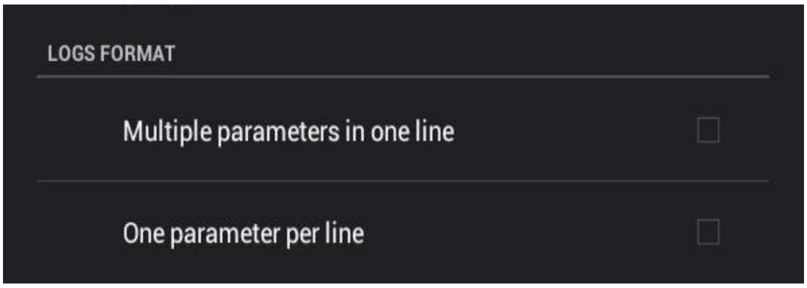


Figure 24 – Logs format

Colour Theme Settings

Allows the operator to choose a colour scheme for the remote screen. (“Matrix”, “Classic”, “Emacs” or “Custom”.

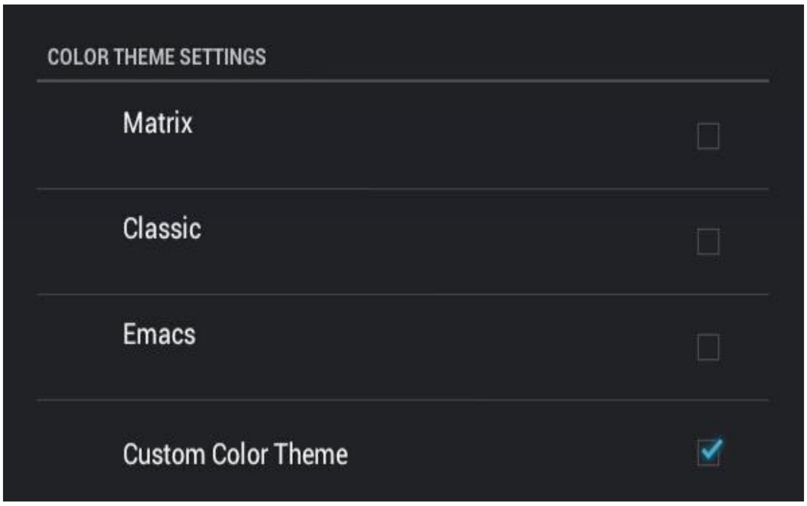


Figure 25 – Colour theme settings

5. Calibration

5.1 Overview

The calibration chapter consists of:

- A general discussion of calibration.
- A description of the multipoint calibration procedure.

The Serinus 10 ozone analyser is a precision measuring device which must be calibrated against a known source of ozone. Ozone concentration standards required for calibration may be generated and assayed with a UV calibration photometer at the time of use, or they may be obtained by means of a certified ozone transfer standard.

In general terms, the calibration process includes the following steps:

1. Establish a reliable and stable calibrating source.
2. Provide a satisfactory connection between the calibration source and the analyser.
3. Calibrate the analyser against the calibration source.

Multipoint calibration is used to establish the relationship between analyser response and pollutant concentration over the analyser's full scale range. Zero and span checks are frequently used to provide a two-point calibration or an indication of analyser stability and function.

Regulations generally require that the analyser be recalibrated any time it is moved, serviced, or whenever the analyser characteristics may have changed. This includes changing the instruments units from volumetric to gravimetric. Regulatory agencies establish the time intervals at which the analyser must be calibrated to ensure satisfactory data for their purposes.

Note: Use of the Serinus 10 O_3 analyser as a U.S. EPA-designated equivalent method requires periodic multipoint calibration in accordance with the procedure described below. In addition, the instrument must be set to the parameters indicated in U.S. EPA Equivalent Set-up section 2.4.

5.2 Photometric Assay Calibration Procedure

Principle

The calibration procedure is based on the photometric assay of ozone (O_3) concentrations in a dynamic flow system. The concentration of O_3 in an absorption cell is determined from a measurement of the amount of 254 nm light absorbed by the sample. This determination requires the knowledge of the following:

- Absorption coefficient (a) of O_3 at 254 nm.
- Optical path length (l) through the sample.
- Transmittance of the sample at a wavelength of 254 nm.
- Temperature (T) and pressure (P) of the sample.

The transmittance is defined as the ratio I/IO, where I is the intensity of light which passes through the cell and is sensed by the detector when the cell contains an O3 sample, and IO is the intensity of light which passes through the cell and is sensed by the detector when the cell contains zero air.

It is assumed that all conditions of the system, except for the contents of the absorption cell, are identical during measurement of I and IO. The quantities defined above are related by the Beer-Lambert absorption law.

$$\text{Transmittance} = \frac{I}{I_O} = e^{-acl}$$

Equation 1 - Beer-Lambert Absorption Law

where:

a = absorption coefficient of O3 at 254 nm = 308 ±4 atm-1 cm- 1 at 0° C and 760 torr (760 torr = 101 kPa)
c = O3 concentration in atmospheres
l = optical path length in cm.

In practice, a stable O_3 generator is used to produce O_3 concentrations over the required range. Each O_3 concentration is determined from the measurement of the transmittance (I/IO) of the sample at 254 nm with a photometer of path length l and calculated from the following equation:

$$c(atm) = -\frac{1}{al}\left(\ln\frac{I}{I_O}\right)$$

Or

Equation 2 - Modified Beer-Lambert Absorption Law

$$c(ppm) = -\frac{10^6}{al}\left(\ln\frac{I}{I_O}\right)$$

Equation 3 Modified Beer-Lambert Absorption Law

The calculated O_3 concentrations must be corrected for O_3 losses which may occur in the photometer and for the temperature and pressure of the sample.

Applicability

This procedure is applicable to the calibration of ambient air O_3 analysers, either directly or by means of a transfer standard certified by this procedure. Transfer standards must meet the requirements and specifications set forth by your local regulatory authority.

Apparatus

A complete UV calibration system consists of an ozone generator, an output port or manifold, a photometer, an appropriate source of zero air, and other components as necessary. The configuration must provide a stable ozone concentration at the system output and allow the photometer to accurately assay the output concentration to the precision specified for the photometer.

Figure 27 shows a commonly used configuration and serves to illustrate the calibration procedure which follows. Other configurations may require appropriate variation in the procedural steps. All connections between components in the calibration system downstream of the O_3 generator should be of glass, Teflon®, or other relatively inert materials.

Additional information regarding the assembly of a UV photometric calibration apparatus is given in Calibration Reference 1. For certification of transfer standards which provide their own source of O_3, the transfer standard may replace the O_3 generator and possibly other components shown in Figure 27.

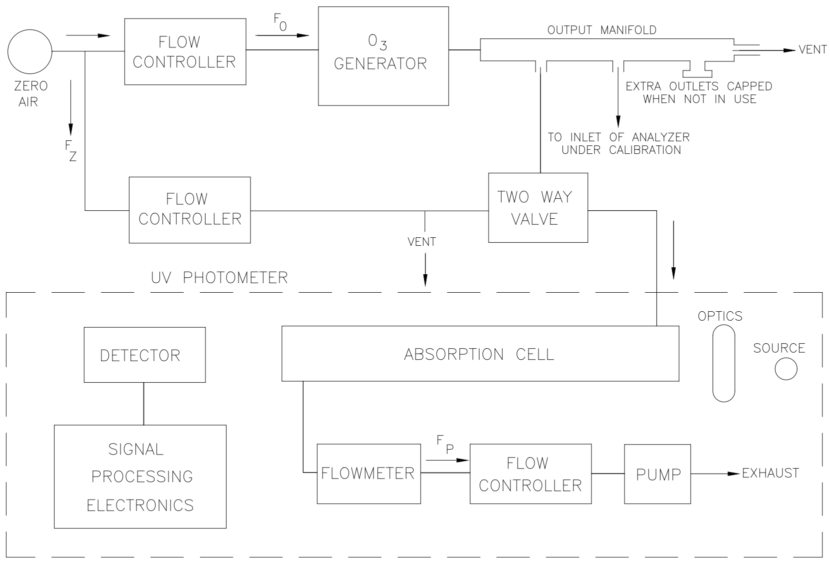


Figure 26 – Typical UV Photometric Calibration System

UV Photometer

The photometer consists of a low-pressure mercury discharge lamp, (optional) collimation optics, an absorption cell, a detector, and signal-processing electronics, as illustrated in Figure 27.

It must be capable of measuring the transmittance, I/IO, at a wavelength of 254 nm with sufficient precision such that the standard deviation of the concentration measurements does not exceed the greater of 0.005 ppm or 3% of the concentration.

As the low-pressure mercury lamp radiates at several wavelengths, the photometer must incorporate suitable means to assure that no O_3 is generated in the cell by the lamp, and that at least 99.5% of the radiation sensed by the detector is 254 nm radiation. (This can be readily achieved by prudent selection of optical filter and detector response characteristics.) The length of the light path through the absorption cell must be known with an accuracy of at least 99.5%. In addition, the cell and associated plumbing must be designed to minimise loss of O_3 from contact with cell walls and gas handling components.

Air Flow Controllers

Devices capable of regulating air flows as necessary to meet the output stability and photometer precision requirements.

Ozone Generator

Device capable of generating stable levels of O_3 over the required concentration range.

Output Manifold

The output manifold should be constructed of glass, Teflon®, or other relatively inert material, and should be of sufficient diameter to insure a negligible pressure drop at the photometer connection and other output ports. The system must have a vent designed to ensure atmospheric pressure in the manifold and to prevent ambient air from entering the manifold.

Two-Way Valve

Automatic valve, or other means to switch the photometer flow between zero air and the O_3 concentration.

Temperature Indicator

Accurate to ±1° C.

Barometer or Pressure Indicator

Accurate to ±2 torr.

Zero Air

The zero air must be free of contaminants which would cause a detectable response from the O_3 analyser, and it should be free of NO, C_2H_4, and other species which react with O_3.. As shown in Figure 27, the zero air supplied to the photometer cell for the IO reference measure-measurement must be derived from the same source as the zero air used for generation of the ozone concentration to be assayed (I measurement). When using the photometer to certify a transfer standard having its own source of ozone.

5.3 Procedure

5.3.1 General Operation

The calibration photometer must be dedicated exclusively to use as a calibration standard. It should always be used with clean, filtered zero air, and never used for ambient air sampling. Consideration should be given to locating the calibration photometer in a clean laboratory where it can be stationary, protected from physical shock, operated by a responsible analyst, and used as a common standard for all field calibrations via transfer standards.

5.3.2 Preparation

Proper operation of the photometer is of critical importance to the accuracy of this procedure. The following steps will help to verify proper operation.

During the first few months of photometer operation, perform the preparation procedure frequently, and record all quantitative results and indications in a chronological record, in the form of a table or graph. When the performance and stability record of the photometer is established, you may be able to perform the procedure less frequently.

1. Instruction manual: Carry out all setup and adjustment procedures or checks as described in the operation or instruction manual associated with the photometer.
2. System check: Check the photometer system for integrity, leaks, cleanliness, proper flow rates, etc. Service or replace filters and zero air scrubbers or other consumable materials, as necessary.
3. Linearity: Verify that the photometer manufacturer has adequately established that the linearity error of the photometer is less than 3%. Otherwise test the linearity by dilution as follows: Generate and assay an O_3 concentration near the upper range limit of the system (0.5 or 1.0 ppm), then accurately dilute that concentration with zero air and re assess it. Repeat at several different dilution ratios. Compare the assay of the original concentration with the assay of the diluted concentration divided by the dilution ratio, as follows:

$$E = \frac{A_1 - A_2 / R}{A_1} * 100\%$$

Equation 4 - Linearity Error Equation

where:

E = linearity error, percent
A1 = assay of the original concentration
A2 = assay of the diluted concentration
R = dilution ratio = flow of original concentration divided by the total flow.

The linearity error must be less than 5%. Since the accuracy of the measured flow rates will affect the linearity error as measured this way, the test is not necessarily conclusive.

Intercomparison: When possible, the photometer should be occasionally intercompared, either directly or via transfer standards, with calibration photometers used by other agencies or laboratories.

Ozone Losses

Some portion of the O_3 may be lost upon contact with the photometer cell walls and gas handling components. The magnitude of this loss must be determined and used to correct the calculated O_3 concentration. This loss must not exceed 5%.

5.3.3 Assay of O_3 Concentrations

1. Allow the photometer system to warm-up and stabilise.
2. Verify that the flow rate through the photometer absorption cell, FP, allows the cell to be flushed in a reasonably short period of time (2 lpm is a typical flow). The precision of the measurements is inversely related to the time required for flushing, since the photometer drift error increases with time.
3. Ensure that the flow rate into the output manifold is at least 1 lpm greater than the total flow rate required by the photometer and any other flow demand connected to the manifold.

4. Ensure that the flow rate of zero air, FZ, is at least 1 lpm greater than the flow rate required by the photometer.
5. With zero air flowing in the output manifold, actuate the two-way valve to allow the photometer to sample first the manifold zero air, then FZ. The two photometer readings must be equal (I = IO).

Note: In some commercially available photometers, the operation of the two-way valve and various other operations discussed in this section may be carried out automatically by the photometer.

6. Adjust the O_3 generator to produce an O_3 concentration as needed.
7. Actuate the two-way valve to allow the photometer to sample zero air until the absorption cell is thoroughly flushed and record the stable measured value of IO.
8. Actuate the two-way valve to allow the photometer to sample the ozone concentration until the absorption cell is thoroughly flushed and record the stable measured value of I.
9. Record the temperature and pressure of the sample in the photometer absorption cell. (refer to Calibration Reference 1 for guidance).
10. Calculate the O_3 concentration from Equation 5 – Beer-Lambert Equation
11. . An average of several determinations will provide better precision.

$$[O_3]_{OUT} = \left(^{-}\frac{1}{al}\ 1n\ \frac{I}{I_O}\right)\left(\frac{T}{273}\right)\left(\frac{760}{P}\right) x\ \frac{10^6}{L}$$

Equation 5 – Beer-Lambert Equation

where:

$[O_3]_{OUT}$ = O_3 concentration, ppm
a = absorption coefficient of O_3 at 254 nm = 308 atm-1 cm-1 at 0° C and 760 torr (760 torr = 101 kPa)
l = optical path length, cm
T = sample temperature, °K
P = sample pressure, torr
L = correction factor for O_3 losses from 5.2.5 = (1-fraction O_3 lost).

Note: Some commercial photometers may automatically evaluate all or part of Equation 5 – Beer-Lambert Equation

It is the operator's responsibility to verify that all of the information required for Equation 5 – Beer-Lambert Equation

is obtained either automatically by the photometer or manually. For automatic photometers which evaluate the first term of Equation 5 – Beer-Lambert Equation

based on a linear approximation, a manual correction may be required, particularly at higher O_3 levels. See the photometer instruction for guidance.

12. Obtain additional O_3 concentration standards as necessary by repeating steps 3 through 10 above, or by Option 1.

5.3.4 Certification of Transfer Standards

A transfer standard is certified by relating the output of the transfer standard to one or more ozone standards as determined according to section 5.3.3 above. The exact procedure varies depending on the nature and design of the transfer standard.

These procedures describe how to calibrate the span and zero point for the analyser.

These procedures describe how to calibrate the span and zero point for the analyser.

The following sections assume the instrument is at the **Calibration Menu** (refer to Section 3.5.9).

5.4 Zero Calibration

Zero calibrations are used to set the zero point of the analyser.

Note: This calibration is unnecessary in most situations and should only be performed if required. Ecotech recommends that zero calibration not be used unless specifically required.

Performing a zero calibration can be performed through either the calibration port or the sample port. Follow the relevant instructions below:

Calibration Port

1. Set “Cal. Type” to “Manual”.
2. Set “Cal. Mode” to “Zero” (to indicate that the measurement sample should be drawn from the calibration port).
3. Ensure a suitable zero source is connected to the calibration port on the back panel of the analyser (refer to Section 2.3.1).
4. Allow the instrument to stabilise for 20 minutes.
5. Select the “Zero Calibration” field and enter 0.0.

Sample Port

1. Set “Cal. Type” to “Manual”.
2. Set “Cal. Mode” to “Measure” (to indicate the measurement sample should be drawn from the sample port).
3. Ensure suitable zero source is connected to the Sample port on the back panel of analyser (refer to Section 2.3.1).
4. Let the instrument stabilise for 20 minutes.
5. Select the “Zero Calibration” field and enter 0.0.

5.5 Span Calibration

A span calibration can be performed through either the calibration port or sample port. Span calibrations calibrate the instrument to the upper limits of normal monitoring.

Ecotech recommends that 90% of full scale should be sufficient for calibrations in ambient monitoring situations 0.450 ppm.

It is good practice to condition the sample lines prior to a span adjustment especially if the sample filter has been recently changed. To do so, first place the analyser in the offline state to invalidate the recorded data. Run a high level of ozone (approximately 1 to 2 ppm) to the analyser for an hour.

Then reduce the level to 0.45ppm and follow the relevant instructions below:

Calibration Port

1. Ensure suitable span gas source is connected to the calibration port on the back panel of analyser (refer to Section 2.3.1).The span gas source must also be measures by your ozone photometer transfer standard.
2. Set the span source to a known concentration (90% full scale recommended).
3. Enter the **Main Menu → Calibration Menu**.
4. Set “Cal. Mode” to “Span”.
5. Let the instrument stabilise (20 minutes).
6. Enter the **Quick Menu** and select “Span Calibrate”.
   (Also accessible through: **Main Menu→Calibration Menu→**”Span Calibrate”).
7. A box will appear with editable numbers. Select the concentration being delivered to the instrument. (Indicated on the transfer standard).
8. The instrument will perform a span calibration, when finished the instrument will return to normal activities.

Sample Port

1. Ensure a suitable span gas source is connected to the sample port on the back panel of analyser (refer to Section 2.3.1). The span gas source must also be measures by your ozone photometer transfer standard.
2. Set the span source to a known concentration (90% full scale recommended).
3. Let the instrument stabilise (20 minutes).
4. Enter the **Quick Menu** and select “Span Calibrate”.
5. A box will appear with editable numbers. Select the concentration being delivered to the instrument. (Indicated on the transfer standard).
6. The instrument will perform a span calibration, when finished the instrument will return to normal activities.

5.6 Multipoint Precision Check

The multipoint involves supplying the instrument with span gas at multiple known concentrations and recording the output of the instrument. Multipoint calibrations are used to determine the linearity of the concentration readings over the range of the multipoint calibration. The instrument gain should not be adjusted to each individual point.

1. Ensure a suitable span source is connected to the instrument from a gas calibrator (Ecotech recommends the GasCal-1100, plus an Ozone Photometer Transfer Standard) through the calibration port.
2. Record analyser instrument gains before performing calibration (refer to Section 3.5.13).
3. Perform a zero check using zero air as described in section 5.4.
4. Perform a span calibration as described in section 5.5.
5. Set up a program for measuring the span concentration through 6 steps down from 75% of full scale.
6. Example for full scale of 0.5ppm:
    a. Set the 1st concentration on the gas calibrator to 375ppb, allow instrument to sample for 20 minutes, record measurement.
    b. Set the 2nd concentration on the gas calibrator to 250ppb, allow instrument to sample for 20 minutes, record measurement.
    c. Set the 3rd concentration on the gas calibrator to 125ppb, allow instrument to sample for 20 minutes, record measurement.
    d. Set the 4th point at a concentration of 0ppm (zero air); allow the instrument to sample for 20 minutes and record measurement.
7. The linearity and correlation can be calculated for each point manually or all points calculated within excel.

Manual Calculations

Record the concentration measurement at each point and determine the percent difference between instrument response and the supplied concentration using the following equation:

$$\frac{\text{Instrument Response} - \text{Supplied Concentration}}{\text{Supplied Concentration}} \times 100 = \text{Percent Difference}$$

Equation 6 - Instrument Accuracy

If the difference between values is less than 1% of full scale then the instrument is within specifications. If not, a Leak Check and/or service are required (refer to Section 6.4.3).

Microsoft Excel

Alternatively all the data can be placed in an Excel spread sheet in columns next to the supplied concentration.

1. Create an X Y scatter plot of expected calibration against instrument response, right click on either point and select "Add Trendline". Tick the "Display equation on chart" and "Display R-squared value on chart" in the options tab.
2. The linear regression equation y = mx + b will be displayed as:

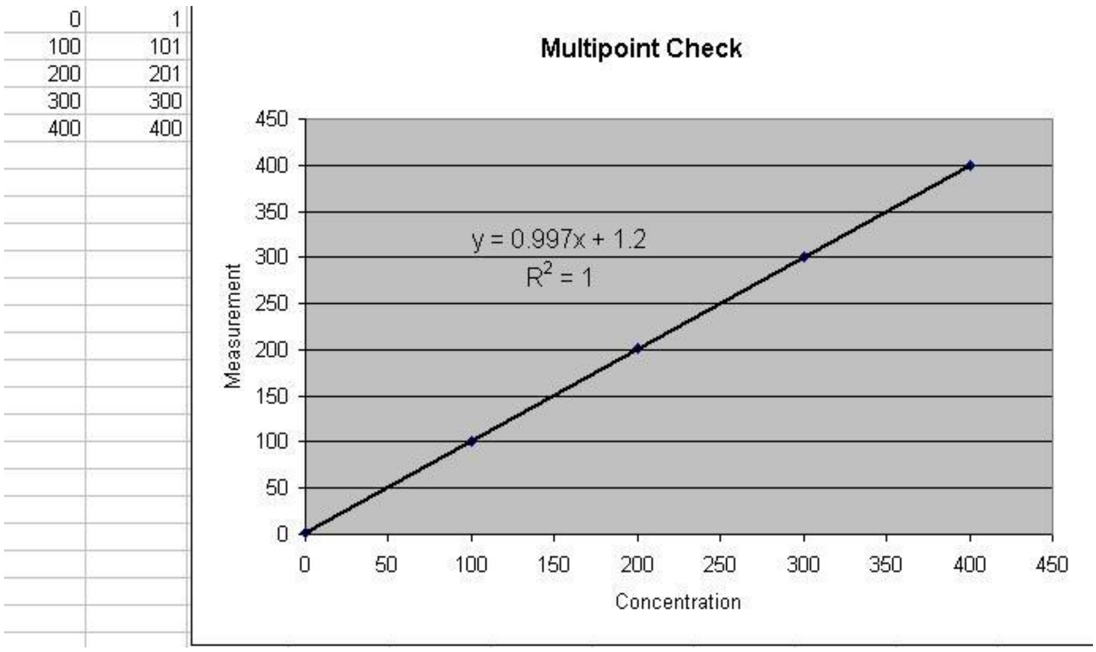


Figure 27 – Excel graph of multipoint calibration

3. Accept the calibration if the following are found:

- The gradient (m) falls between 0.98 and 1.02.
- The intercept (b) lies between -0.3 and +0.3.
- The correlation (R2) is greater than 0.9995.

4. Reject the calibration if the above criteria are not met; if these measurements do not match step 7. If the calibration fails, perform a leak check (refer to Section 6.4.3), check zero air scrubbers or check troubleshoot guide for possible errors (refer to Section 7).

5.7 Precision Check

A precision check is a Level 2 calibration. This means that the instrument has a known span gas concentration, or zero air, run through it and an observation of the instruments concentration is made with no adjustment. A precision check can be performed either manually or automatically. Refer to your regional standards for appropriate pass/fail criteria.

5.8 Pressure Calibration

The pressure calibration involves a two point calibration, one point under vacuum and another point at ambient pressure. To perform a pressure calibration the following steps must be completed.

Note: The vacuum calibration must be performed first when performing a full pressure calibration.

Vacuum

1. Enter **Calibration Menu** → "Pressure Calibration" and "Open".

Note: This action will place the valve sequence on hold.

2. Select "Vacuum Set pt." → "OK".

Figure 28 – Pressure calibration

3. Disconnect tubing from sample port and then connect an external pressure meter to instruments sample port. See Figure 29.

Figure 29 - Pressure calibration; external pressure meter

4. Connect vacuum source to exhaust port of analyser, and switch vacuum source on.

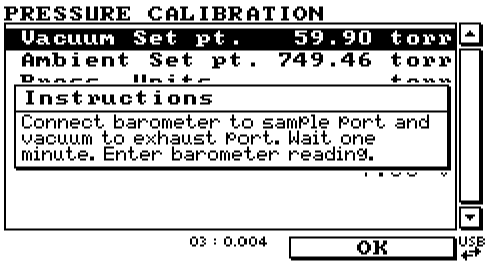


Figure 30 – Vacuum set point screen

5. Ensure that the pressure reading on the external meter is stable. Now edit the “Vacuum Set pt.” value to equal the pressure measured by the external meter.

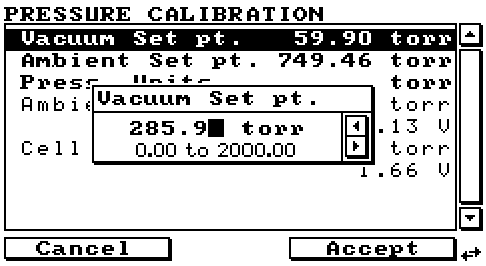


Figure 31 – Editing vacuum set point

6. Press the “Accept” button to calibrate pressure sensor.
7. The instrument menu will now take you to the Ambient Set pt.

Figure 32 – Ambient set point calibration screen

8. Switch off and disconnect any vacuum source connected to the instruments Exhaust port.
9. Disconnect the pressure meter.

Ambient

1. Obtain the current ambient pressure with a pressure meter.
2. Enter the **Main Menu → Calibration Menu → Pressure Calibration →**”Ambient Set pt.” (If continuing from the vacuum pressure calibration this step is not necessary).

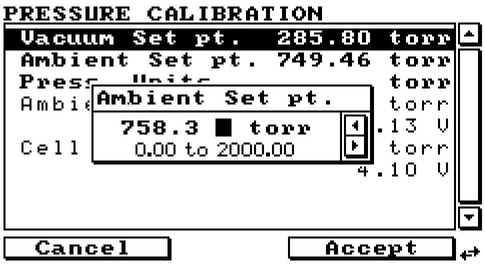


Figure 33 – Setting the ambient set point

3. Using the keypad input the current ambient pressure.
4. Press the “Accept” button to calibrate pressure sensors.
5. Exit the **Pressure Calibration Menu**.
6. Reconnect all external tubing to rear of analyser.

5.8.1 Menus

When the internal pump is installed in the analyser the following menus are added, unique only to instruments with an internal pump.

Pressure & Flow Menu

Flow SetPoint	The flow that the internal pump is set to draw through the analyser.

Calibration Menu -> Flow Calibration

This menu contains all the controls for calibrations with an internal pump.

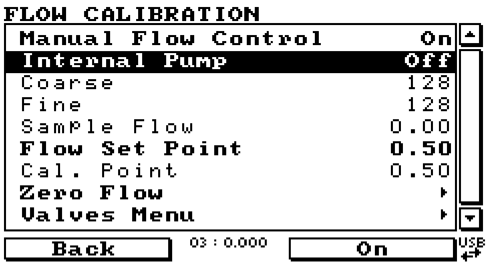
Sample Flow	Current gas flow (This is only accurate when reading close to the “Cal. Point”, as documented below).
Flow Set Point	The flow that the internal pump is set to control to.
Cal. Point	Point to which the flow calibration is performed to (must be calibrated at “Flow set point” for accurate flow control).
Zero Flow	When there is no flow through instrument (“Sample Flow” = 0) select this field to calibrate the zero flow point.
Internal Pump	This field allows the internal pump to be turned ON or OFF. This field is only editable when “Manual Flow Control” field is set to “On” (below).
Manual Flow Control	Enable or disable the automatic flow control and internal pump.

Coarse	Internal pump speed control (Coarse).
Fine	Internal Pump speed control (Fine). Fine should only be used in the range 252 to 255. **Note**: Coarse and Fine are not selectable when the flow control is enabled.
Valves Menu	Opens **Valve Menu** where individual valves can be open and shut (refer to Section 3.5.16 for **Valve Menu**).

5.8.2 Flow Calibration (Internal pump option only)

The following procedure must be performed if the instrument has been set back to factory defaults, external flow check has found the flow to be outside normal range or if flow rate set points need to be changed.

1. Disconnect all external tubing.
2. Go to **Main Menu** → **Calibration** → **Flow Calibration**.



3. Go to the **Valve Menu** and set “Valve sequencing” to OFF.
4. Set Span/Zero and Cal port valves to “Closed”.
5. Return to the Flow **Calibration Menu**.
6. Set the “Flow Control” field to “Disabled”.
7. Set the internal pump to OFF.
8. Wait for the sample flow to become stable around 0 (Stability of ± 0.01).

Note: Make sure that the “Flow Setpoint” and the “Cal. Point” are both present to 0.50.

9. Press “Zero Flow” → press “Set” (sample flow should not change).
10. Pop up will display “Zero flow/set current flow as zero flow?” select “YES”.
11. Connect a calibrated flow meter to the sample port on the back of the analyser.
12. Set internal pump “ON”.
13. Manually adjust the coarse and fine pots until the flow meter reads the desired (set point) flow = 0.5.

Note: et fine pot to 253, then adjust coarse to be as close as possible to desired reading, then use fine pot to make it exact.

14. Enter the reading from the flow meter into the “Cal. Point” field.
15. Set the “Flow Control” field to “Enabled”.
16. Go to the **Valve Menu** and set “Valve Sequencing” to ON.
17. (**Main Menu → Service Menu → Diagnostics → Valve Menu**)
18. Leave for up to 5 minutes to return to normal operation. If instrument doesn’t return to normal there may be a blockage, see section 7.1.

5.8.3 Pressure Calibration with Internal Pump

1. Go to **Main Menu → Calibration → Flow Calibration.**
2. Go to the **Valve Menu** and set “Valve Sequencing” to “OFF”.
3. Set Span/Zero and Cal port valves to “Closed”.
4. Return to the Flow **Calibration Menu**.
5. Set the “Flow Control” field to “Disabled”.
6. Set the “Coarse” pot to 254.
7. Set the “Fine” pot to 230.
8. Connect a calibrated barometer to the sample port on the back of the analyser (remove sample tubing).
9. Return to the **Calibration Menu**.
   Instrument will prompt user “Do you want to resume the flow control” select “NO”.
10. Under the **Pressure Calibration Menu** select “Vacuum” and select units as “TORR” .
11. Allow 1 to 2 minutes for the pressure reading to stabilise to vacuum (both barometer and analyser).
12. Press “EDIT” and enter the measure reading from the barometer and press accept.
13. Return to the **Flow Calibration Menu.**
14. Set the internal pump off.
15. Remove barometer from sample port.
16. Return to the **Calibration Menu**.
    Instrument will prompt user “Do you want to resume the flow control” select “NO”.
17. Under the **Pressure Calibration Menu** select “Ambient” and select units as “TORR”.
18. Allow 1 to 2 minutes for the pressure reading to stabilize to ambient (both barometer and analyser).
19. Press “EDIT” and enter the measured reading from the barometer and press accept.
20. Go to the **Pressure & Flow Menu** (**Main Menu → Analyser State**) and compare the “Ambient” and “Cell” pressures to each other. If they are within 5 TORR of each other pressure calibration was fine, if they are >± 5 TORR repeat pressure calibration procedure.

21. When completed return to the “Flow Control” field and set to “Enabled”.
22. Go to the **Valve Menu** and set “Valve Sequencing” to “ON”.
23. The procedure is now completed.

5.9 Pressurised Zero Valve

If the analyser was ordered with the optional pressurised zero valve then the internal pressurised zero calibration valve is already installed within the analyser (refer to Figure 55) as a zero calibration source, thus no other connections need to be made.

Operation of Single Calibration Option

When using the pressurised zero calibration option a high pressure zero bottle should be connected to the “Auxiliary In” port on the back of the analyser.

1. Ensure gas cylinder is fitted with an appropriate gas regulator with shut off valve.
2. Connect a line of 1/8” stainless steel tubing between the gas cylinder and the analyser’s auxiliary port inlet.

Note: This connection may need to be retightened during this operation.

3. Open the cylinder main valve and adjust the regulator to 15 psig or 1 bar.
4. Open the regulator shutoff valve and leak test.
5. Temporarily place a flow meter on the calibration port inlet (used as a vent).
6. Enter the **Calibration Menu** (**Main Menu** → **Calibration Menu**)
7. Change “Set Cal Port” to “External”.
8. Select “Zero” under the “Cal Mode”, this will initiate the pressurised calibration.
9. Open the cylinder shutoff valve, adjust the regulator pressure until the flow on the vent line (Calibration port) is between 0.5 and 1 lpm.

Note: Do not exceed 2 bar of pressure; it may create a leak in the system.

Return to Normal Operation

1. Set “Cal. Mode” → “Measure”.
2. Remove the flow meter on the calibration port and connect a ¼” vent line to port.
3. Reconnect instrument fittings and place in original set-up.
4. The instrument is now in normal operation mode.

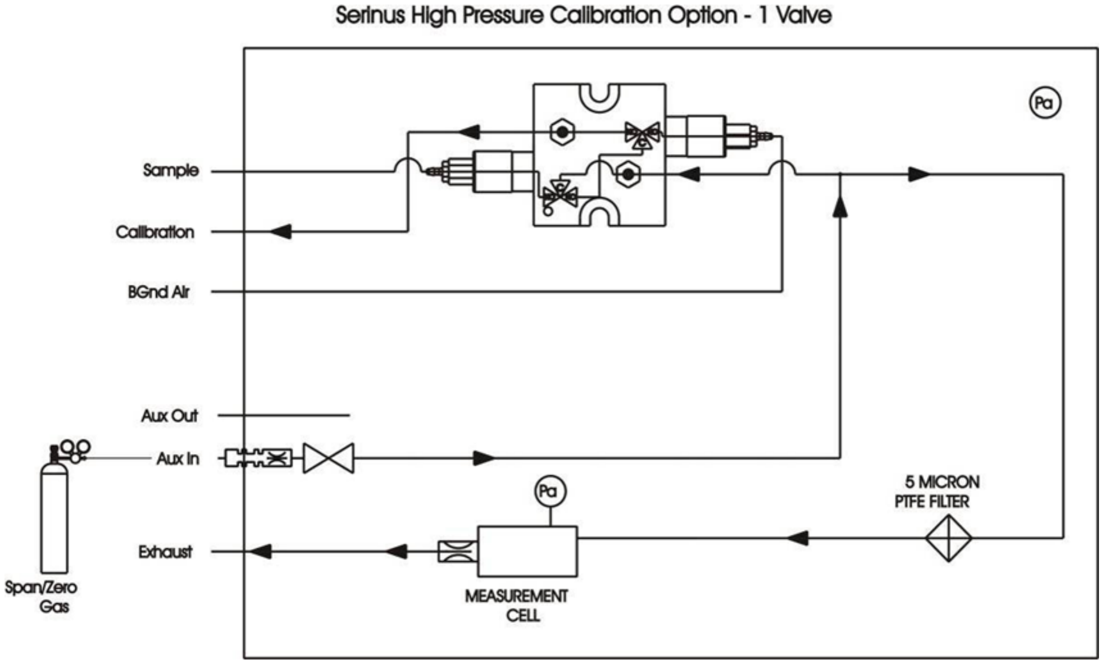


Figure 34 – Single high pressure zero calibration option

5.10 Precision Check

A precision check is a Level 2 calibration. This means that the instrument has a known concentration of span gas (or zero air) run through it and an observation of the instrument's concentration is made with no adjustment. A precision check can be performed either manually or automatically. If an instrument fails a precision check (based on your local applicable standards), perform a span calibration (refer to Section 5.5) or zero calibration (refer to Section 5.4) where appropriate.

6. Service

6.1 Pneumatic Diagram

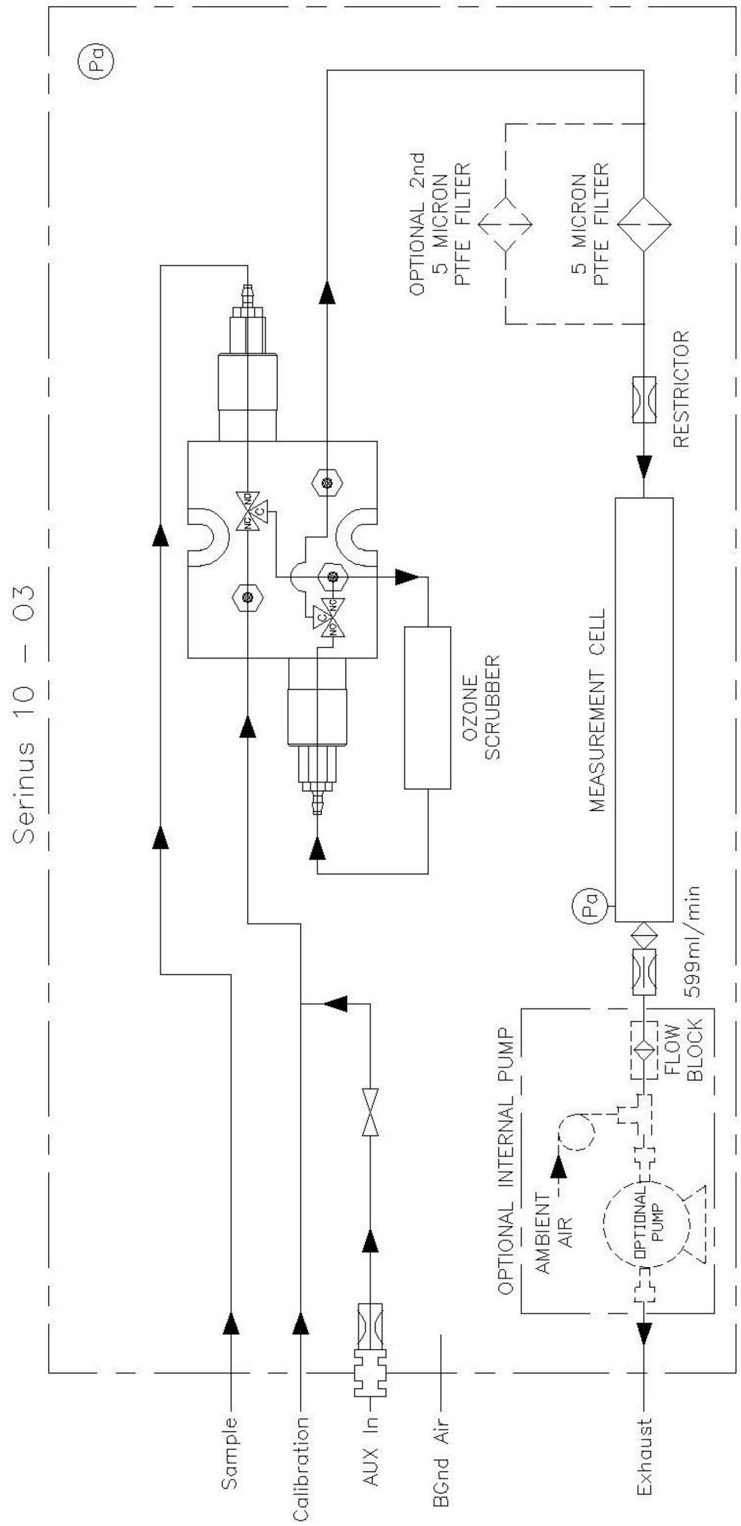


Figure 35 - Serinus 10 pneumatic diagram

6.2 Maintenance Tools

To perform general maintenance on the Serinus 10 the user may require the following equipment:

- Digital multimeter (DMM).
- Computer or remote data terminal and connection cable for RS232 or USB communication.
- Pressure transducer (absolute) and connection tubing.
- Flow meter (1 slpm nominal)
- Minifit extraction tool PN: T030001
- Orifice removal tool PN: H010046
- 1.5mm hex key
- Assortment of 1/4" and 1/8" tubing and fittings.
- Zero air source.
- Span gas source.
- Leak test jig PN: H050069
- Isopropyl alcohol
- Latex gloves
- Cotton buds

6.3 Maintenance Schedule

Table 2 - Maintenance Schedule

Interval *	Task performed	Page
Weekly	Check inlet particulate filter, replace if full/dirty	92
	Check sample inlet system for moisture or foreign materials. Clean if necessary	
	Perform precision check	82
Monthly	Check fan filter, clean if necessary	92
	Perform Span calibration	80
	Check date and time is correct	42
6 Monthly	Check ozone scrubber, replace if exhausted	94
	Perform multi-point calibration check	81
Yearly	Clean Pneumatic tubing	95
	Replace sintered filter and orifice (only if necessary)	98

	Check UV lamp, replace if necessary	97
	Perform a leak check	93
	Perform pressure check	98

*Suggested intervals for maintenance procedure may vary with sampling intensity and environmental conditions.

6.4 Maintenance Procedures

6.4.1 Particulate Filter Replacement

Contamination of the filter can result in degraded performance of the analyser, including slow response time, erroneous readings, temperature drift, and various other problems.

1. Disconnect the external pump.
2. Slide open the lid of the analyser to access the particulate filter (located in front right hand corner).
3. Unscrew the filter cap (bright blue) by turning it counter-clockwise.
4. Remove the filter plunger from the casing, place finger on tubing connector and pull to the side (refer to Figure 36).

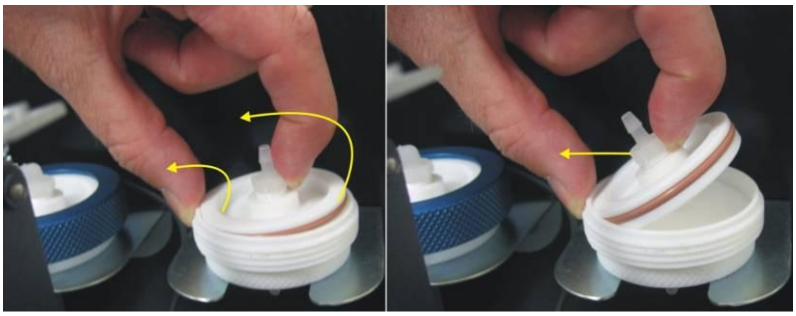


Figure 36 - Removing plunger

5. Remove the old filter, wipe down the plunger with a damp cloth and insert new filter.
6. Replace the plunger, screw the cap on and reconnect the pump.
7. Close the instrument and perform a leak check (refer to Section 6.4.3).

6.4.2 Clean Fan Filter

The fan filter is located on the rear of the analyser. If this filter becomes contaminated with dust and dirt it may affect the cooling capacity of the analyser).

The fan filter is located on the rear of the analyser. If this filter becomes contaminated with dust and dirt it may affect the cooling capacity of the analyser.

1. Disconnect the fan power cable.
2. Remove outer filter casing and filter (refer to Figure 37).

3. Clean filter by blowing with compressed air (if available) or shaking vigorously.
4. Replace filter and filter casing

Figure 37 - Removing fan filter

6.4.3 Leak Check

If a leak is suspected a more intensive leak check can be performed.

Equipment Required:

- Source of vacuum (pump)
- Leak test jig
- Swagelok ¼” blocker nut

Leak Check Procedure

1. Connect the leak check device to the exhaust port of the analyser.

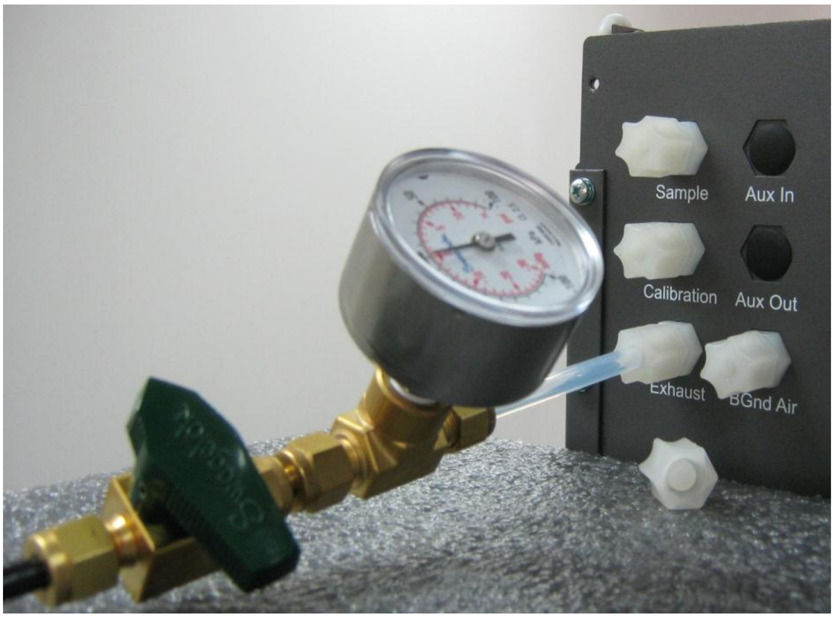


Figure 38 – Pressure gauge on exhaust

2. Connect the vacuum to the shut off valve ensuring the shut off valve is in the open position.

3. Switch on the analyser navigate to the **Valve Menu**. **Main Menu →Service Menu → Diagnostic → Valve Menu**. Disable "Valve Sequencing".
4. Block the analyser's 'Sample and 'Calibration' ports with Swagelok ¼" blocker nuts.
5. Close the shut off valve and record the vacuum. Wait 3 minutes, observe the gauge on the leak check jig, it should not drop more than -5kpa. If it has, then a leak is present.
6. If the instrument was found to be leak free then skip to point number 9.
7. Inspect the instrument's plumbing within the sample measure cycle looking for obvious damage. Check the condition of fittings, sample filter housing, O-rings both in the filter assembly and in the cell assembly.
8. When the location of the leak has been determined and repaired, then rerun the leak check procedure.
9. Open the shut off valve.
10. Navigate to the **Valve Menu**. **Main Menu →Service Menu → Diagnostic → Valve Menu**. Open "Span/Zero Select".
11. Close the shut off valve and record the vacuum. Wait 3 minutes observe the gauge on the leak check jig it should not drop more than -5kpa. If it has, then a leak is present.
12. If the instrument was found leak free then skip to point number 15.
13. Inspect the instrument's plumbing within the calibration measure cycle looking for obvious damage. Check the condition of fittings and the calibration valve assembly.
14. When the location of the leak has been determined and repaired, then rerun leak check procedure.
15. Once more inspect tubing ensure tubing is cleanly connected to fittings and the internal Teflon lining has not been kinked or crumpled.
16. Remove the leak check jig and Swagelok blocking nuts.
17. Turn off or reset the analyser.

6.4.4 Ozone Scrubber Check

The performance of the ozone scrubber is critical to the Serinus 10. Although the ozone scrubber will theoretically last forever (if only exposed to clean air and ozone), exposure to other elements in the atmosphere will adversely affect the life span of the scrubber. A weak or failed scrubber can result in noisy measurements, frequently caused by excessively high gain.

If a faulty ozone scrubber is suspected perform the following steps:

1. Connect a source of span gas (approx 0.400 ppm O_3) to the sample inlet, allow the instrument to stabilise then record the response.
2. Replace the scrubber with a test ozone scrubber (see below for instructions). Allow the instrument to stabilize and record the response.
3. Compare the two readings. If the second reading exceeds the first by more than 10% the scrubber should be replaced.

Scrubber Replacement

1. Unscrew the retaining nut located on the elbow of the scrubber to be changed. Disconnect the tubing from the joint.
2. Remove the scrubber from the retaining clip.
3. Unscrew the retaining nut on the elbow joint at the bottom of the scrubber. Disconnect the tubing from the joint.
4. Connect the tubing to the new scrubber and tighten the retaining nut at the bottom of the new scrubber.
5. Press the scrubber into the retaining clip and connect the tubing to the top elbow joint. Tighten the retaining nut.

6.4.5 Clean Pneumatics

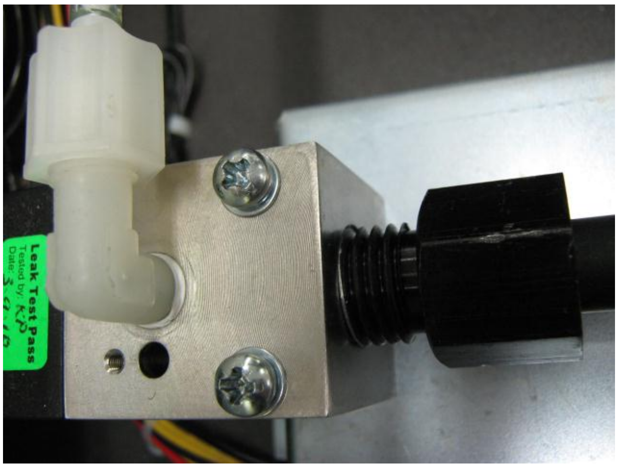
The simplest method is to replace the tubing. The valve manifold will require disassembling and cleaning. Ideally the vales and manifold should be cleaned in a sonic bath with soppy water. Once clean, rinse with distilled water and dry before reassembling. A leak test should be performed once the analyser is ready for service (refer to Section 6.4.3).

If new tubing is not available then the pneumatic lines (sample and exhaust) may be cleaned by removing and washing with a methanol cotton swab and dried by blowing with zero air or dry nitrogen. Do not clean the scrubber. Cleaning the reaction cell can be performed as shown in the procedure below.

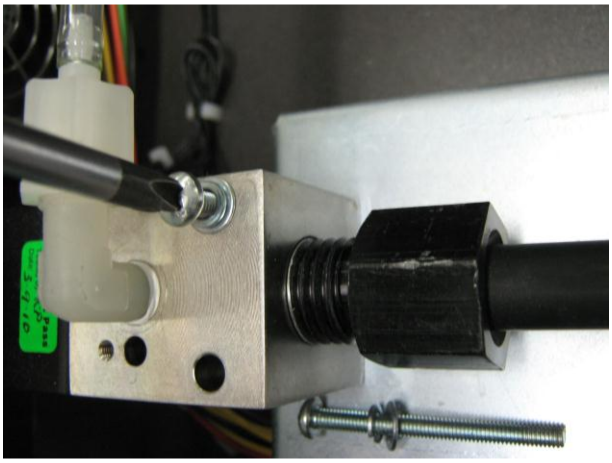
Note: After tube or cell cleaning the analyser should be allowed to sample O_3 at approximately 0.400 ppm overnight to recondition the pneumatics prior to calibration.

Cell Cleaning

1. Loosen the retaining nut from the detector side of the glass tube casing (measurement tube).



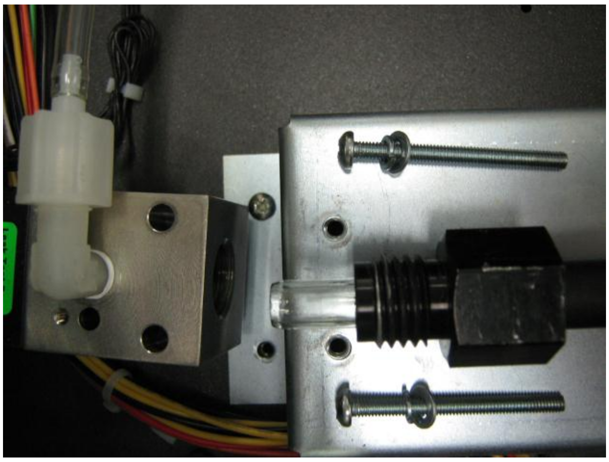
2. Remove the two screws holding the detector block to the optical bench (metal plate).



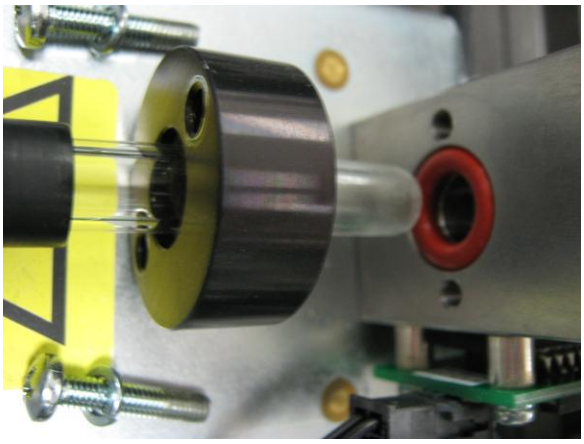
3. Slowly move side to side and pull the detector block away from the tube removing it completely.

CAUTION

Be careful while installing or removing the tube, as it may fracture and cause serious injury to the operator.



4. Remove the two retaining screws around the measurement tube (lamp end).



5. Pull the casing back away from the lamp block then carefully remove the glass tube slowly moving side to side and pulling out.

6. Inspect the tube for any particulate matter deposited on the inner walls of the tube. If any residue is detected, the entire pneumatic system should be cleaned. Do not clean the ozone scrubber.
7. Clean the glass tube by swabbing with clean, soapy water in both directions. Rinse in deionized water, then in isopropyl alcohol. Dry in air, no lint, grease, or particulate matter should be present.
8. Replace the casing and nut onto the glass and carefully replace the glass into lamp block to the end. Push the glass through to the end of the detector block then pull back ¼ inch.
9. Place the detector block onto the glass and slowly move (side to side) up the glass cell until the block holes align with those on the metal plate.
10. Replace screws in the detector block and tighten the retaining nut.
11. Perform the leak test, if leak test fails then the cell probably hasn't made a seal with the O-ring in the detector block, repeat steps 8-11.

6.4.6 UV Lamp Check

The UV lamp intensity decreases over time, to compensate for this the instrument will increase the UV lamp pot. When the digital pot (Input Pot) reaches 255 the lamps intensity is not suitable for accurate measurement and the lamp should be replaced.

UV Lamp Replacement

1. Turn the analyser off.
2. Open the analyser.
3. Disconnect the lamp from the lamp driver PCB (located under the reaction cell).

   Remove the grub screw (1.5mm hex key) from the hole in the left side of the block (refer to Figure 39) securing the UV lamp and slide the lamp out of the block.

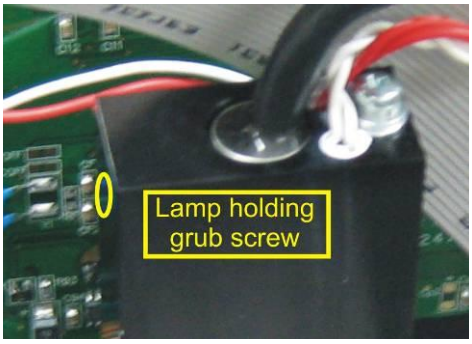


Figure 39 - Location of UV lamp fastening grub screw

4. Remove UV lamp.
5. Install the new UV lamp in reverse order of the above steps. Be sure to insert the lamp completely in the block to achieve maximum signal strength.

CAUTION

Be careful when securing lamp with grub screw not to tighten too much and damage lamp.

6. Turn instrument on and allow one hour to stabilise.
7. Perform a zero and span calibration (refer to Sections 5.4 and 5.5).

6.4.7 Orifice Replacement

In the situation where the ozone analyser's orifice must be replaced the following procedure should be followed.

1. Turn analyser off and disconnect vacuum source from analyser.
2. Remove tubing from the Kynar fitting from the block at the lamp end of the measurement bench.
3. Unscrew the Kynar fitting from the block (refer to Figure 40).

Figure 40 - Kynar fitting containing orifice

4. Use the orifice removal tool to remove the orifice from within the block.
5. Replace with new orifice and replace all tubing/fittings in reverse order.
6. Perform a leak test (refer to Section 6.4.3).
7. Perform zero and span calibrations (refer to Sections 5.4 and 5.5).

6.4.8 Pressure Sensor Check

Pressure checks are needed to ensure that the pressure sensor is accurately measuring pressure inside the instrument

During normal operation ensure that the pressure and flow menu indicate the following parameters. Ambient should display the current ambient pressure at site. Cell should indicate current cell pressure depending on the pump condition and location. The cell pressure is normally about 10 torr below ambient.

To navigate to the pressure and flow menu. Enter **Main Menu → Analyser State → Pressures and Flow**.

1. A simple way of checking the pressure sensors response is to disconnect the exhaust and sample tubing from the back of the analyser. After 2-5minutes observe the pressure readings: ambient and cell. Ensure that they are reading the same ± 3 torr (± 0.4 kPa).
2. If the readings are outside this level then perform a pressure calibration (refer to Section 5.8).

3. If the calibration fails then the instrument may have a hardware fault. The cell pressure PCA has test points. To determine if the pressure sensor is faulty simply measure the voltage on the test points show in the photos. The voltage measured across the test point is proportional to the pressure measured by the sensor so if the sensor is exposed to ambient pressure at sea level then the voltage will be around 4 volts but if the sensor is under vacuum then the voltage will be low for example 0.5 volts. If the test point measures zero of negative voltage then the assembly is most likely faulty and will need to be replaced.

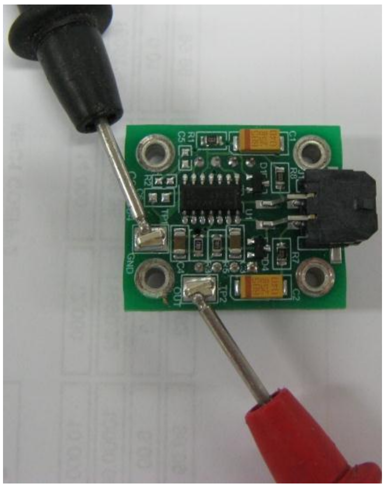


Figure 41 – Test point location.

Figure 42 – Typical test point reading of cell pressure sensor.

6.4.9 Battery Replacement

The replaceable battery (BT1) on the main controller board may need to be replaced. If the clock resets or does not increment when the power is off, then the battery is going flat. The battery should be replaced with the correct type of battery, a 3V Lithium CR2025 type should be used and installed correctly as follows:

1. Turn off the Instrument, open the lid and remove the 2 screws holding down the main controller PCB.
2. Lift the PCB up to its open position. The battery (BT1) is located toward the front of the PCB
3. Using a small flat screwdriver, lift the metallic clip holding the battery whilst sliding the old battery out.

4. Now place the new battery in with the positive (+) side facing up.
5. Close the main PCB and return the screws. Close the lid again.
6. Turn on the instrument and set the clock time and date in the "**General Settings**" menu (refer to Section 3.5.8).

6.5 Parts List

Below is a list of the replaceable parts of the Serinus 10. Some of these parts will almost never require replacing and other consumables will need replacing on a routine basis. Ecotech provides a yearly consumables kits which contains many of the consumable necessary for one year of maintenance.

Table 3 - Spare Parts List

Part Description	Part Number
Tube Reaction Cell	H013113
LCD and Interface Assembly	C010010
PCA, Controller	E020220
Power Supply, Serinus	P010003
PCA, Back panel	C010002
PCA, Pressure Sensor	H010031
PCA, Lamp Driver	C010006
PCA, Ozone Detector	C010007
Sample valve manifold assembly	H010013-01
Heater and thermistor assembly	C020073
Tube UV	H013111
Spring Compression	H010047-01
Serinus 10 User Manual	M010026
Fitting, Kynar, elbow 1/8NPT - 1/8 barb	F030005
Gasket, pressure sensor	H010037
Extraction Tool Orifice and Filter	H010046

Table 4 – Serinus 10 Maintenance Kit

Serinus 10 Maintenance Kit	E020201
Filter, Sintered qty 1	F010004
Window, quartz qty 1	H013112
O-ring BS112, silicone, qty 1	O010005
O-ring, Mtg block, lamp end	O010008
O-ring 0.364ID x 0.07W, Viton qty 2	O010010
O-ring 0.114ID x 0.07W, Viton qty 2	O010012
O-ring 1 11/16ID X 3/32W viton qty 2	O010014
O-ring 1/4ID X 1/16W, viton qty 2	O010015
O-ring 13/16ID x 1/16W, Viton qty 2	O010016
O-ring BS015, Viton qty 2	O010023
O-ring, quartz window qty 1	O010024
O-ring, reaction cell tube qty 2	O010025
Tygon tubing (3ft)	T010011

Table 5 – Other Consumables – Not listed in Maintenance Kit

Other Consumables (not listed in maintenance kit)	
Filter paper Teflon 47MM pack of 50	F010006-01
Filter paper Teflon 47MM pack of 100	F010006
Silicone heatsink compound	C050013
Scrubber ozone	H013120
Lamp assy, UV, ozone, Serinus	C020077
Orifice – Sample (10mil)	H010043-09
External pump repair kit (suite 607 pump)	P031001

6.6 Bootloader

The Serinus Bootloader is the initial set of operations that the instruments microprocessor performs when first powered up. (Similar to the BIOS found in a personal computer). This occurs every time the instrument is powered up or during instrument resets. Once the instrument boots up it will automatically load the instrument's firmware. A service technician may need to enter the state between the Bootloader and the firmware load.

To do this power up the instrument and immediately press the plus key multiple times until the following screen appears:

```
** Ecotech Serinus Analyser **
V2.1 Bootloader
Press '1' to enter Bootloader
```

If the analyser displays the normal start up screen then the power will need to be toggled and another attempt will need to be made to enter the Bootloader screen. Once successful

Press 1 to enter the **Bootloader Menu**.

6.6.1 Display Help Screen

Once in the Bootloader screen it is possible to redisplay the help screen by pressing 1 on the key pad.

6.6.2 Communications Port Test

This test is very useful for fault finding communication issues. It allows a communication test to be carried out independent to any user settings or firmware revisions.

This command forces the following communication ports to output a string of characters: serial port RS232 #1, USB rear, and ethernet port. The default baud rate is 38400 for the RS232 serial port. To initiate the test press the number 2 key from the Bootloader screen.

6.6.3 Updating Firmware

It is important for optimal performance of the Serinus analyser that the latest firmware is loaded onto the analyser. The latest firmware can be obtained by visiting Ecotech's website.

http://www.ecotech.com/downloads/firmware

or by emailing Ecotech at service@ecotech.com.au or **intsupport@ecotech.com**

To update the firmware from a USB memory stick, use this procedure;

6.6.4 Upgrade from USB Memory Stick

USB Memory Stick Update

1. Turn instrument off.
2. Place USB memory stick with new firmware (ensure that firmware is placed in a folder called FIRMWARE) in the front panel USB port.
3. Enter the Bootloader (refer to Section 6.6).
4. Select option 3, (Upgrade from USB memory stick) press 3 on keypad.
5. Wait till upgrade has completed.
6. Press 9 to start the analyser with new firmware.

6.6.5 Erase All Settings

This command is only required if the instruments firmware has become unstable due to corruption. To execute command enter into **Bootloader Menu** and select key 4.

6.6.6 Start Analyser

The start analyser command will simply initiate a firmware load by pressing key 9 from the **Bootloader Menu**. It is generally used after a firmware upgrade.

7. Troubleshooting

Table 6 - Troubleshooting List

Error Message/ Problem	Cause	Solution
Blank screen	Contrast set too low	Increase contrast by holding down the Up button for 3-5 seconds
Input pot limited to 0 or 255	Damaged lamp	Replace Lamp, if that is unsuccessful then replace PCB
Lamp Adjust Error	Lamp pot out of range (above 150)	Adjust lamp by adjusting pot, if adjusting lamp doesn't bring down pot under 150
Flow fault	Multiple causes	Troubleshoot 7.1
Reset Detection	Firmware fault	Check that the instrument is not overheating. Possibly a faulty power supply. Corrupted firmware perform and 'erase all settings' in the **Bootloader Menu** and reload or upgrade firmware.
Electronic zero adjust	Faulty zero air or pneumatics	Troubleshoot
12 V Voltage supply failure	Power supply has failed	Replace power supply
Flow block temp	Faulty electronics	Replace flow block
Stabilization	Noise level of reference voltage outside tolerance	Replace lamp or lamp power supply
Lamp temp failure	Faulty heater or temperature sensor	Troubleshoot 7.3
Sample pressure too high or too low	Loss of calibration	Too High - Re-calibrate pressure sensors. Too Low – Check calibration and sample flow
Sample flow not at 500 cc/min	Loss of calibration	Check/replace sintered filter Check/replace sample filter. Check pump. Check valves.

Error Message/ Problem	Cause	Solution
Unstable zero/span	Zero air source, span source, leaky instrument, hardware issues.	Ensure calibration system is functioning correctly. Ensure sufficient gas is available for instrument and an adequate vent is available for excess gas. Perform a through leak check of the instrument, Faulty optical bench. See section 7.2
Unable to span	Confirm O_3 source is accurate. Check for leaks, ensure excess O_3 flow vented to atmosphere	Ensure you are using photometer transfer standard that has yearly calibration certificate, ensure ozone generator can produce 4000 cc/min of span gas. Perform a through leak check.

7.1 Flow Fault

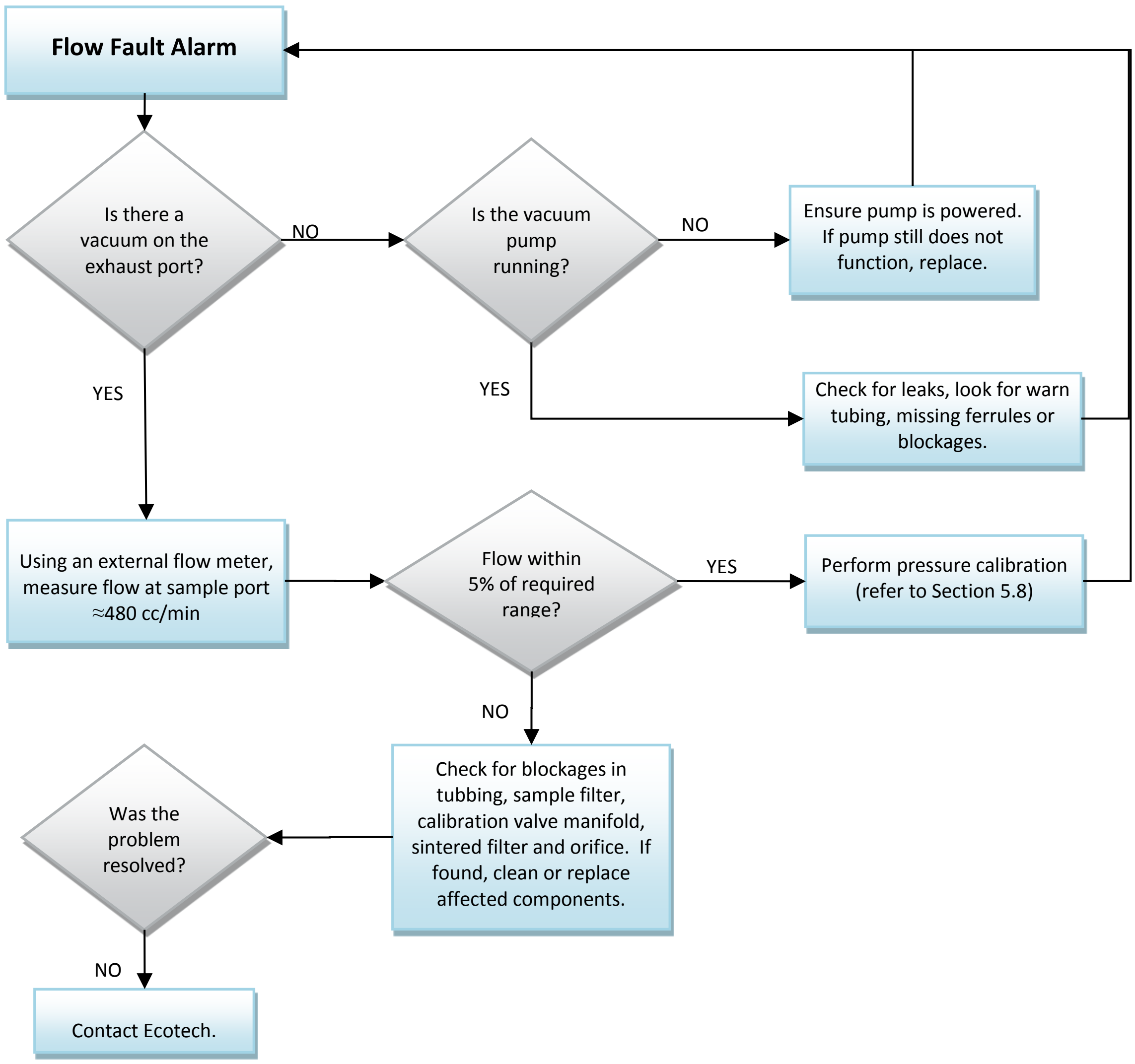


Figure 43 - Flow fault diagnostic procedure

7.2 Noisy Zero or Unstable Span

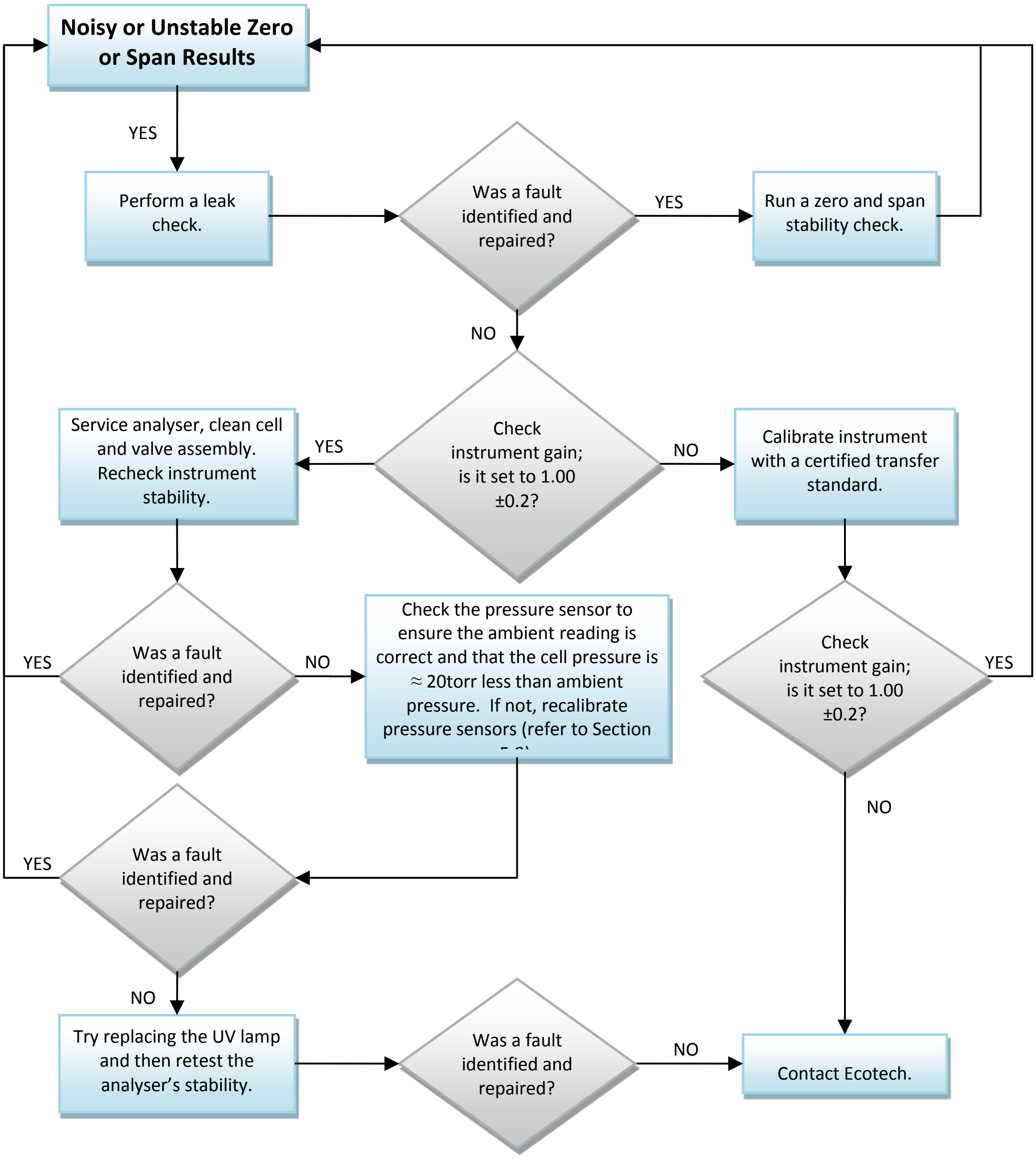


Figure 44 - Noisy zero or unstable span diagnostic procedure

7.3 Lamp Temperature Failure

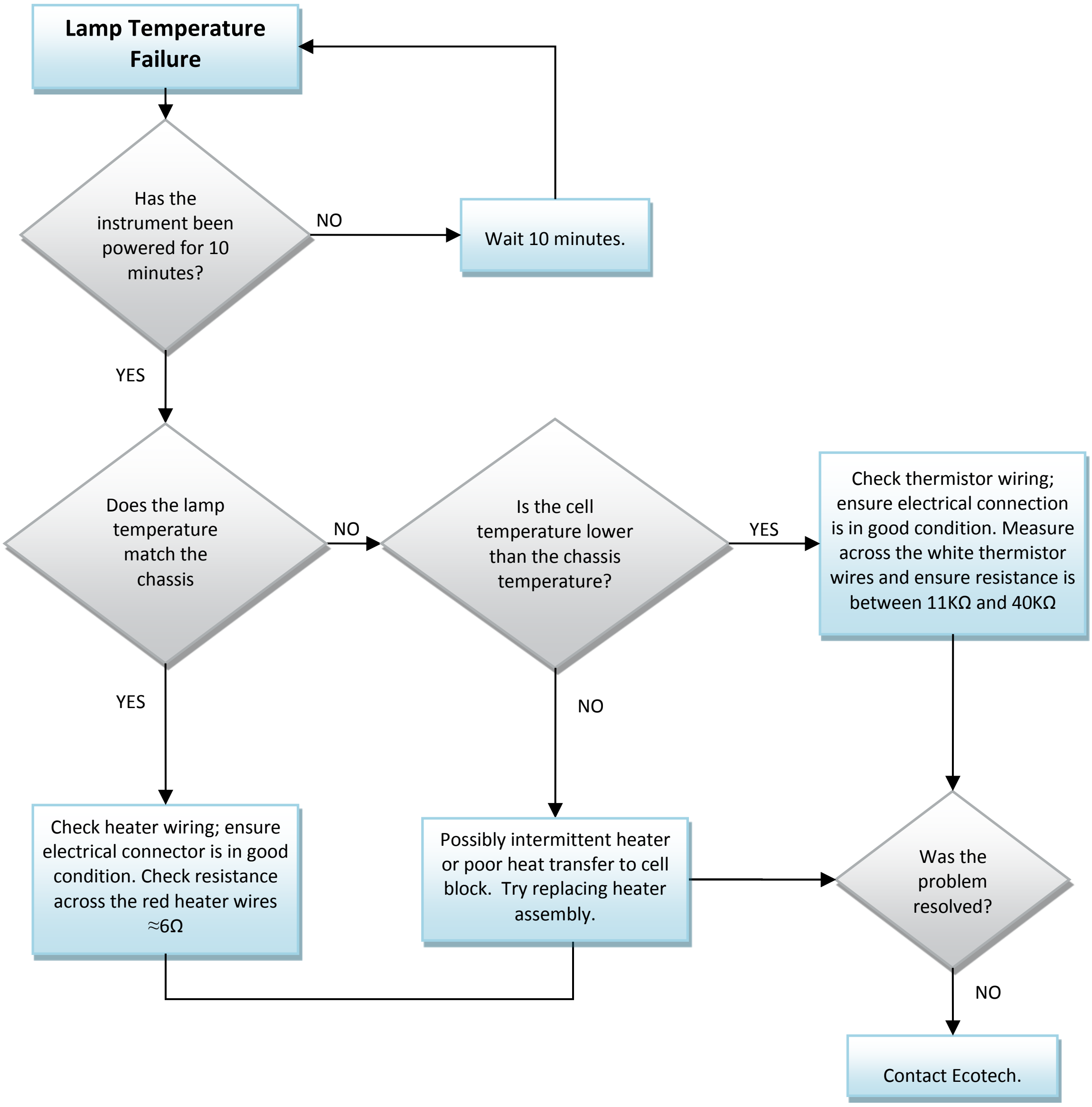


Figure 45 - Lamp temperature failure diagnostic procedure

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8. Optional Extras

8.1 Dual sample filter PN E020100

The dual filter is designed with two sample filters plumbed in parallel with a split line. This formation allows sample flow not to be affected, yet reduces the loading on each filter and therefore the frequency with which they will need to be changed.

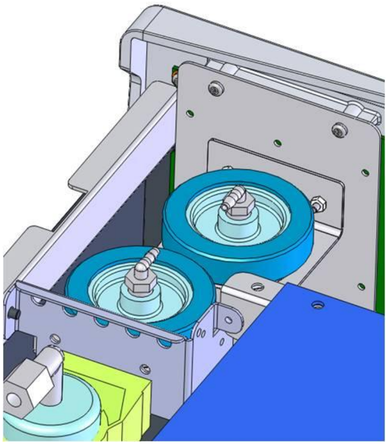

Figure 46 - Dual filter option installed

8.2 Rack Mount Kit PN E020116

The rack mount kit is necessary for installing the Serinus into a 19" rack. The Serinus is 4RU in height, to install in the rack follow these steps.

Included Items

1	Rack Slide Set	H010112
4	Rack Mount Adaptors	H010133
2	Rack Mount Ears	H010134
4	Spacers	HAR-8700
8	M6 x 20 Button Head Screws	
16	M6 Washers	
8	M6 Nyloc Nuts	
14	M4 x 10 Button Head Screws	
8	M4 Washers	
8	M4 Nyloc Nuts	
4	M4 x 10 Phillips Pan Head Screws	
8	M6 Cage Nuts	

Installing the Instrument

1. Remove the rubber feet from the analyser (if attached).
2. Separate the slide rail assembly by pressing the black plastic clips on the slide rails to remove the inner section of the rail. (refer to Figure 47).

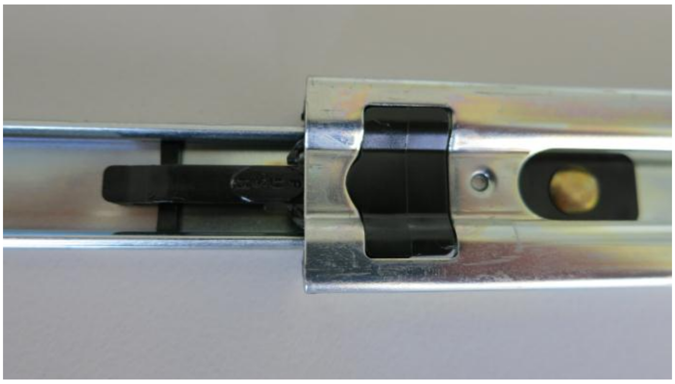

Figure 47 - Separate rack slides

3. Attach the inner slide rails to each side of the analyser using M4 x 10 button screws - three on each side. Ensure the vertical slotted holes are used and push the slide firmly downwards so that the screws sit at the top of the slot. This ensures that any protrusions under the base of the analyser do not hit any blanking panels which may be fitted. (refer to Figure 48).

Figure 48 - Assemble inner slide on chassis

4. Attach the rack mount adaptors to the ends of the outer slide rails using M4 x 10 button screws, washers and locknuts. Do not fully tighten at this stage as minor adjustments may be required to suit the length of the rack (refer to Figure 49).

Figure 49 - Attach rack mount adaptors to outer slides

5. Install the two assembled outer slide rails onto the left and right side of the rack securely with M6 bolts, washer and locknuts. It should be mounted at the front of the rack with the fasteners for this claw located in the 5th and 7th hole of the vertical rail, counting from the bottom position of the instrument (refer to Figure 51 - Attach rack mount adaptors to outer slides

Figure 50 - Assemble inner slide on chassis

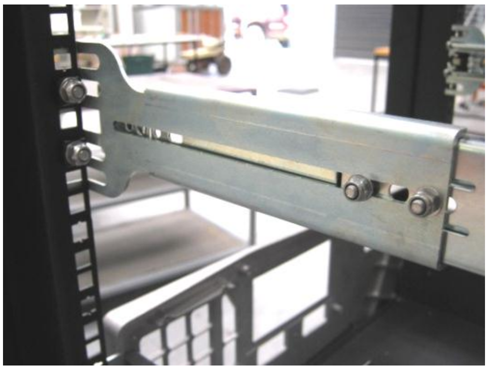

Figure 51 - Attach rack mount adaptors to outer slides

6. Use a spacer (or cage nut) to space the rear claw from the side of the rack and a washer and locknut to secure it (refer to Figure 52).

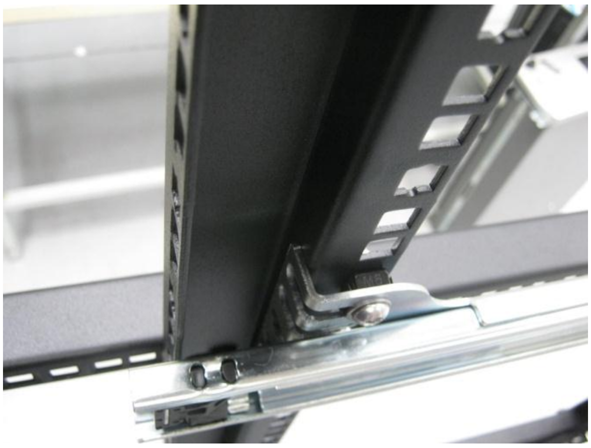

Figure 52 – Attach rear rack mount adaptors to slide

7. Install rack mount ears on the front of the instrument using two M4 x 10 screws on each side (refer to Figure 53).

Figure 53 – Fit Serinus into Slides

8. Now carefully insert the instrument into the rack by placing the instrument slides into the mounted slides. Ensuring that the rack slide locks engage on each side (you will hear a click from both sides). Gently slide the instrument into the rack.

Note: Ensure both sides of the inner slide are attached to the outer slides before pushing into the rack fully.

9. Push the analyser fully in. At this point, make sure that the analyser slides reach and locate in to the plastic catches at the rear end of the outer slides. Adjust the outer slides as required until this is achieved. Remove analyser and now tighten the M4 screws and nuts that secure the front and rear claws on both sides of the rack.

To Remove the Instrument

1. To remove the instrument first pull instrument out of rack giving access to the slides.
2. Find the rack slide lock labelled "push" and push it in whilst sliding the instrument out of the rack. Complete this for both sides before carefully removing instrument.

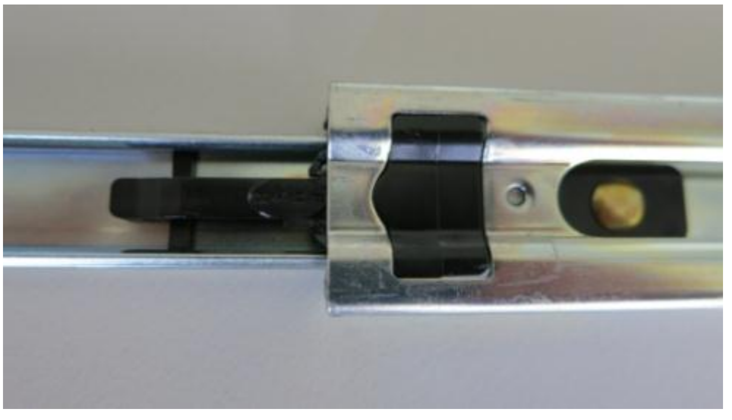

Figure 54 – Slide clips

8.3 Internal Pump PN P030005

8.3.1 Component Changes

The Serinus 10 internal pump option includes and removes the following components:

Table 7 - Internal Pump Components

Component	Description	Part Number
Added components		
Internal pump	Pulls sample air through instrument, strength of pulling is dependent on temperature and pressure readings	H010027
Flow block	Includes sintered filter and differential pressure sensor to measure flow	H010120
Heater and Thermistor	Mounted in flow block to measure and control temperature for accurate flow	Installed in flow block
Removed components		
Sintered filter		F010004
O-ring (X 2)		O010012
Orifice		H010043-09
Spring		H010040

8.3.2 Pressures & Flow

This menu has additional items when the internal pump is installed.

Flow Set Point

Editable field that sets the flow rate that internal pump will sample at (recommended 0.500 lpm).

8.3.3 Calibration Menu

This menu has additional items when the internal pump is installed.

Flow Calibration

This menu contains all the controls for calibrations with an internal pump (refer to Section 8.3.4).

8.3.4 Flow Calibration

A new menu is available with the internal pump installed.

Manual Flow Control

Enable or disable the automatic flow control and internal pump. The state of this item controls whether many of the following items can be edited.

Internal Pump

This field allows the internal pump to be turned on or off manually, instead of under automatic control. This field is only editable when "Manual Flow Control" field is enabled.

Coarse

Internal pump speed control (Coarse). This field is only editable when "Manual Flow Control" field is enabled and the "Internal Pump" field is on.

Fine

Internal pump speed control (Fine). Fine should only be used in the range 252 to 255. This field is only editable when "Manual Flow Control" field is enabled and the "Internal Pump" field is on.

Sample Flow

Current Gas flow. This is only accurate when reading close to the Cal. Point, as documented below.

Flow Set Point

The flow that the internal pump is set to.

Cal. Point

Point to which the flow calibration is performed to (must be calibrated at "Flow Set Point" for accurate flow control). This field is only editable when "Manual Flow Control" field is enabled and the "Internal Pump" field is on.

Zero Flow

When there is no flow through instrument (“Sample flow” = 0) select this field to calibrate the zero flow point. This field is only editable when the “Manual Flow Control” field is enabled and the “Internal Pump” field is turned off.

Valves Menu

Opens **Valve Menu** where individual valves can be open and shut (refer to Section3.5.16).

8.3.5 Flow Calibration Procedure

The internal pump requires a separate flow calibration procedure. The following procedure must be performed after any changes to fittings or filters.

1. Open the Flow **Calibration Menu** from the Calibration Menu (refer to Section 8.3.3).
2. Open the **Valve Menu** and set “Valve Sequencing” to “Off”.
3. Set “Span/Zero Select” and “Cal port valves” to “Closed”.
4. Return to the Flow **Calibration Menu** and set the “Manual Flow Control” field to “On”.
5. Set the “Internal Pump” to “On”.
6. Set the “Cal. Point” to “0.50”.
7. Set the “Internal Pump” to “Off”.
8. Set the “Flow Set Point” to “0.50”.
9. Wait for the sample flow to become stable around 0 (Stability of ± 0.01).
10. Select Zero Flow and select “Yes”.
11. Connect a calibrated flow meter to the Sample port on the back of the analyser.
12. Set the “Internal Pump” to “On”.
13. Set the “Fine” item to 253.
14. Adjust the “Coarse” until the flow meter reads the desired set point flow (0.5) or as close as possible.
15. Adjust the “Fine” until the flow meter reads the desired set point flow (0.5) or as close as possible.
16. Enter the reading from the flow meter into the “Cal. Point” field.
17. Set the “Manu Flow Control” field to “Off”.
18. Go to the **Valve Menu** and set “Valve sequencing” to “On”.
19. Allow up to 5 minutes for the instrument to return to normal operation. If instrument doesn’t return to normal there may be a blockage (refer to Section 7.1).

8.3.6 Pressure Calibration Procedure

The pressure calibration procedure is modified to allow the internal pump to generate the necessary vacuum.

1. Open the Flow **Calibration Menu** from the **Calibration Menu** (refer to Section 8.3.3).
2. Open the **Valve Menu** and set “Valve Sequencing” to “Off”.
3. Set “Span/Zero Select” and “Cal port valves” to “Closed”.
4. Return to the **Flow Calibration menu** and set the “Manual Flow Control” field to “On”.
5. Set the “Internal Pump” to “On”.
6. Set the “Coarse” item to 254.
7. Set the “Fine” item to 230.
8. Connect a calibrated barometer to the sample port on the back of the analyser (remove sample tubing).
9. Return to the **Calibration Menu** and enter the **Pressure Calibration Menu.**
10. Wait until the pressure meter reading and the “Cell” reading on the instrument display are stable.
11. Select the “Vacuum Set pt.” and enter the pressure meter reading.
12. Return to the **Calibration Menu** and enter the **Flow Calibration Menu.**
13. Set the “Internal Pump” to “Off”.
14. Remove barometer from sample port.
15. Return to the “**Calibration Menu**” and enter the **Pressure Calibration Menu**.
16. Wait until the pressure meter reading and the “Ambient” and “Cell” readings on the instrument display are stable.
17. Select the “Ambient Set pt.” and enter the pressure meter reading.
18. Go to the **Main Menu → Analyser State → Pressures & Flow Menu** and compare the “Ambient” and “Cell” pressures to each other. If they are within 5 TORR of each other pressure calibration is acceptable; if they are >± 5 TORR repeat pressure calibration procedure.
19. Return to the “Manual Flow Control” field and set to “Off”.
20. Return to the **Valve Menu** and set “Valve sequencing” to “On”.

8.4 Pressurised Zero Valve PN E020109

If the analyser was ordered with the optional pressurised zero valve then the optional internal pressurised zero calibration valve will be installed within the analyser (refer to Figure 55) as a zero check source, thus no other connections need to be made.

Note: This is NOT intended as a source for calibrating the instrument. This should only be used as an operational check (i.e. Level 2 calibration) of the instrument’s zero point.

Operation of Single Calibration Option

When using the pressurised zero calibration option a high pressure zero bottle should be connected to the "Auxiliary In" port on the back of the analyser.

1. Ensure gas cylinder is fitted with an appropriate gas regulator with shut off valve.
2. Connect a line of 1/8" stainless steel tubing between the gas cylinder and the analyser "Auxiliary port" inlet.

Note: This connection may need to be retightened during this operation.

3. Open the cylinder main valve and adjust the regulator to 15 psig or 1 bar.
4. Open the regulator shutoff valve and leak test.
5. Temporarily place a flow meter on the calibration port inlet (used as a vent).
6. Enter the **Calibration Menu** (refer to Section 3.5.11).
7. Change "Set Cal Port" to "External".
8. Select "Zero" under the "Cal. Mode", this will initiate the pressurised calibration.
9. Open the cylinder shutoff valve, adjust the regulator pressure until the flow on the vent line (Calibration port) is between 0.5 and 1 lpm.

Note: Do not exceed 2 bar of pressure, if this occurs a leak may exist.

Return to Normal Operation

1. Set "Cal. Mode" to "Measure".
2. Remove the flow meter on the calibration port and connect a ¼" vent line to port.
3. Reconnect instrument fittings and place in original set-up.

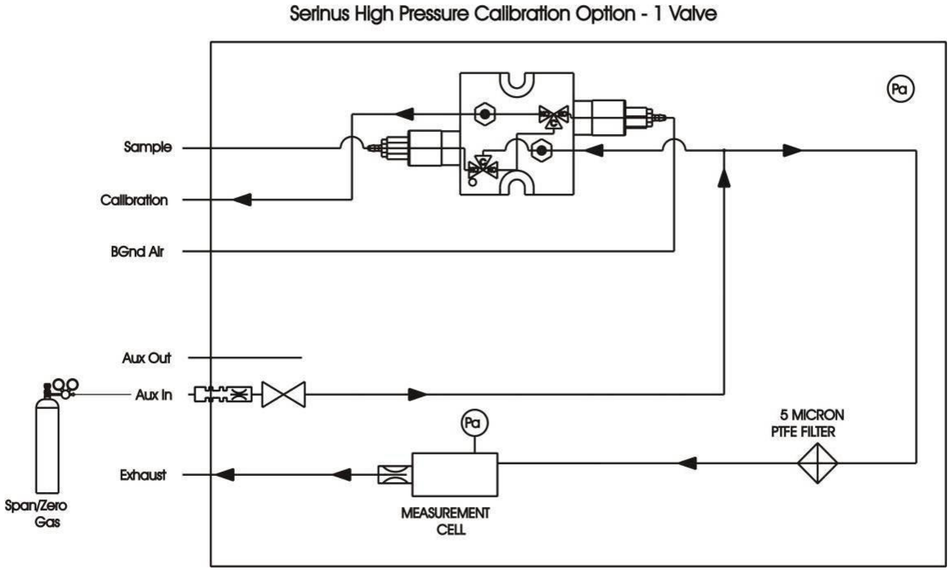

Figure 55 - Single high pressure zero calibration option

Appendix A. Advanced Protocol Parameter List

Note: Parameters are for all Serinus analysers and may not be applicable to an individual analyser.

Table 8 - Advanced Protocol Parameter List

#	Description	Notes
0	Sample / Cal Valve	0=Sample, 1=Cal/Zero
1	Cal / Zero Valve	0=Zero, 1=Cal
2	Internal Span Valve	0=Closed, 1=Open
3	Spare Valve 1	0=Closed, 1=Open
4	Spare Valve 2	0=Closed, 1=Open
5	Spare Valve 3	0=Closed, 1=Open
6	Spare Valve 4	0=Closed, 1=Open
7	NO_X Measure Valve	0=NO, 1=NO_X
8	NO_X Bypass Valve	0=NO, 1=NO_X
9	NO_X Background Valve	0=Closed, 1=Open
10	Valve Sequencing	0=Off, 1=On
11	LCD Contrast Pot	0=Lightest, 255=Darkest
12	SO_2 REFERENCE ZERO Gain Pot	S50 Reference ZERO POT
13	CO Measure Gain Pot	S30 Measure Gain Adjust
14	CO Reference Gain Pot	
15	CO Test Measure Pot	SEE 149. EXISTS
16	& PMT HIGH VOLTAGE Pot	High Voltage Controller Pot for PMT S50 & S40
17	SO_2 Lamp ADJ Pot	S50 Lamp Adjust Pot
18	O_3 Lamp ADJ Pot	S10 Lamp Adjust Pot
19	O_3 ZERO Measure Pot: Coarse	S10 Signal Zero (coarse)
20	O_3 ZERO Measure Pot: Fine	S10 Signal Zero (fine)
21	PMT Fan Pot	PMT fan speed controller Pot
22	Rear Fan Pot	CHASSIS Fan speed control POT
23	PUMP SPEED Motor Driver Pot: Fine	INTERNAL Pump speed fine POT
24	PUMP SPEED Motor Driver Pot: Coarse	INTERNAL Pump speed coarse POT
25	Analogue input 0	SO_2 REFERENCE SIGNAL
26	Analogue input 1	CO REFERENCE SIGNAL
27	Analogue input 2	O_3 REFERENCE SIGNAL

#	Description	Notes
28	Analogue input 3	SO_2 & O_3 LAMP CURRENT
29	Analogue input 4	FLOW BLOCK PRESSURE
30	Analogue input 5	CELL PRESSURE
31	Analogue input 6	AMBIENT PRESSURE
32	Analogue input 7	RAW ADC CALIBRATION INPUT
33	Analogue input 8	MFC1 NOT USED
34	Analogue input 9	CONCENTRATION DATA
35	Analogue input 10	MFC2 NOT USED
36	Analogue input 11	MFC3 NOT USED
37	Analogue input 12	EXTERNAL ANALOG INPUT 0
38	Analogue input 13	EXTERNAL ANALOG INPUT 1
39	Analogue input 14	EXTERNAL ANALOG INPUT 1
40	Analogue input 15	MFC0 NOT USED
41	CO Measure Pot : Coarse	S30 Measure ZERO Coarse adjustment Pot
42	CO Measure Pot: Fine	S30 Measure ZERO Fine adjustment Pot
43	SO_2 Measure SIGNAL Gain Pot	SO_2 Measure Signal Gain Pot
44	SO_2 REFERENCE Gain Pot	SO_2 YReference Signal Gain Pot
45	SO_2 SIGNAL ZERO	SO_2 Measure Zero Pot
46	O_3 SIGNAL GAIN POT	O_3 INPUT SIGNAL GAIN POT
47	Test Pot	Test Pot for all the analysers
48	NO_X Signal GAIN Pot	PMT signal input gain control FOR NOX
49	PGA Gain	1, 2, 4, 8, 16, 32, 64, 128
50	Primary Gas Concentration	Current value on front screen
51	Secondary Gas Concentration	Current value on front screen (if applicable eg $NO_{x)}$
52	Calculated Gas Concentration	Gas 3 (eg:NO_2)
53	Primary Gas Average	Average of the readings(for Gas1) of the last n minutes where n is the averaging period
54	Secondary Gas Average	
55	Calculated Gas Average	
56	Instrument Gain	
57	Main Gas ID	
58	Aux Gas ID	
59	Decimal Places	2-5

#	Description	Notes
60	Noise	
61	Gas 1 Offset	
62	Gas 3 Offset	
63	Flow Temperature	
64	Lamp Current	
65	Digital Supply Voltage	Digital Supply voltage (should always read close to 5 volts)
66	Concentration Voltage	
67	PMT High Voltage	High Voltage reading for PMT
68	Ozonator Status	0=Off, 1=On
69	Control Loop	
70	Diagnostic Mode	
71	Gas Flow	
72	Gas Pressure	
73	Ambient Pressure	
74	12V Supply Voltage	The 12 volt Power supply voltage
75	Cell Temperature	
76	Converter Temperature	
77	Chassis Temperature	
78	Manifold Temperature	
79	Cooler Temperature	
80	Mirror Temperature	
81	Lamp Temperature	
82	$O_)$ Lamp Temperature	
83	Instrument Status	
84	Reference Voltage	
85	Calibration State	0 = MEASURE 1 = CYCLE 2 = ZERO 3 = SPAN
86	Primary Raw Concentration	(before NO_x background and gain)
87	Secondary Raw Concentration	(before NO_x background and gain)
88	NO_x Background Concentration	(before gain)

#	Description	Notes
89	Calibration Pressure	
90	Converter Efficiency	
91	Multidrop Baud Rate	
92	Analog Range Gas 1	
93	Analog Range Gas 2	
94	Analog Range Gas 3	
95	Output Type Gas 1	1=Voltage 0=Current
96	Output Type Gas 2	1=Voltage 0=Current
97	Output Type Gas 3	1=Voltage 0=Current
98	Voltage Offset /Current Range Gas1	0=0% or 0-20mA 1=5% or 2-20mA 2=10% or 4-20mA
99	Voltage Offset /Current Range Gas2	0=0% or 0-20mA 1=5% or 2-20mA 2=10% or 4-20mA
100	Voltage Offset /Current Range Gas3	0=0% or 0-20mA 1=5% or 2-20mA 2=10% or 4-20mA
101	Full Scale Gas 1	5.0 Volt Calibration value for Analog Output 1
102	Full Scale Gas 2	5.0 Volt Calibration value for Analog Output 2
103	Full Scale Gas 3	5.0 Volt Calibration value for Analog Output 3
104	Zero Adjust Gas 1	0.5 Volt Calibration value for Analog Output 1
105	Zero Adjust Gas 2	0.5 Volt Calibration value for Analog Output 2
106	Zero Adjust Gas 3	0.5 Volt Calibration value for Analog Output 3
107	Negative 10V Supply	
108	NA	Unsupported
109	NA	Unsupported
110	Instrument State	
111	CO Linearisation Factor A	
112	CO Linearisation Factor B	
113	CO Linearisation Factor C	

#	Description	Notes
114	CO Linearisation Factor D	
115	CO Linearisation Factor E	
116	Instrument Units	0= PPM 1=PPB 2=PPT 3=mG/M^3 4=µG/M^3 5=nG/M^3
117	Background Measure Time	In seconds
118	Sample Fill Time	In seconds
119	Sample Measure Time	In seconds
120	Aux Measure Time	In seconds
121	Aux Sample Fill Time	In seconds
122	Background Fill Time	In seconds
123	Zero Fill Time	In seconds
124	Zero Measure Time	In seconds
125	Span Fill Time	In seconds
126	Span Measure Time	In seconds
127	Span Purge Time	In seconds
128	Background Pause Time	In seconds
129	Background Interleave Factor	In seconds
130	Calibration Pressure 2	
131	AUX Instrument Gain	
132	Background voltage	
133	AUX Background Voltage	
134	O_3 Generator Output	PPM
135	O_3 Generator On/Off	
136	Calibration Point 1	PPM
137	Calibration Point 2	PPM
138	Calibration Point 3	PPM
139	Calibration Point 4	PPM
140	Calibration Point 5	PPM
141	Desired Pump Flow	SLPM

#	Description	Notes
142	Actual Pump Flow	SLPM
143	Set Lamp Current	%
144	Lamp Current	mA
145	Cycle Time	Minutes
146	CO Cooler Pot	CO Cooler voltage adjustment POT
147	CO Source Pot	CO Source voltage adjustment POT
148	CO MEASURE Test Pot 0	CO MEASURE TEST POT
149	CO REFERENCE Test Pot 1	CO REFERENCE TEST POT
150	O_3 REF Average	S10 Background Average
151	PTF Gain 0	Pressure Temperature Flow Compensation Factor for first gas
152	PTF Gain 1	Pressure Temperature Flow Compensation Factor for second gas in dual gas analysers.
153	Inst. Cell Pressure	Instantaneous cell pressure
154	Manifold Pressure	Valve Manifold Pressure
155	Cell Gas 1 Pressure	Cell Pressure for Gas 1
156	Cell Gas 2 Pressure	Cell Pressure for Gas 2
157	Cell Bgnd Pressure	Cell Pressure when in Background
158	Reserved	
159	Reserved	
160	Reserved	
161	Temperature Units	0 = "ºC", 1 = "ºF", 2 = "ºK",
162	Pressure Units	0 = "torr", 1 = "psi", 2 = "mbar", 3 = "atm", 4 = "kPa"

#	Description	Notes
163	Averaging Period	0 = " 1 Min", 1 = " 3 Mins", 2 = " 5 Mins", 3 = "10 Mins", 4 = "15 Mins", 5 = "30 Mins", 6 = " 1 Hr", 7 = " 4 Hrs", 8 = " 8 Hrs", 9 = " 12 Hrs", 10 = " 24 Hrs"
164	Filter Type	NO FILTER = 0, KALMAN FILTER = 1, 10 SEC FILTER = 2, 30 SEC FILTER = 3, 60 SEC FILTER = 4, 90 SEC FILTER = 5, 300 SEC FILTER = 6, ADPTIVE FILTER =7
165	NO_2 Filter	0 = Disabled, 1 = Enabled
166	Background Interval	0 = "24 Hrs", 1 = "12 Hrs", 2 = "8 Hrs", 3 = "6 Hrs", 4 = "4 Hrs", 5 = "2 Hrs", 6 = "Disable"
167	Service Baud	0 = " 1200 bps", 1 = " 2400 bps ", 2 = " 4800 bps ", 3 = " 9600 bps ", 4 = "14400 bps ", 5 = "19200 bps ", 6 = "38400 bps "

#	Description	Notes
168	Multidrop Baud	0 = " 1200 bps", 1 = " 2400 bps ", 2 = " 4800 bps ", 3 = " 9600 bps ", 4 = "14400 bps ", 5 = "19200 bps ", 6 = "38400 bps "
169	Service Port (COM 1) Protocol	0 = " EC9800", 1 = "Bavarian", 2 = "Advanced"
170	Multidrop Port (COM 2) Protocol	0 = " EC9800", 1 = "Bavarian", 2 = "Advanced"
171	Gas1 Over Range	The Upper Concentration Range when Over-Ranging is enabled for Analog Output 1
172	Gas2 Over Range	The Upper Concentration Range when Over-Ranging is enabled for Analog Output 2
173	Gas3 Over Range	The Upper Concentration Range when Over-Ranging is enabled for Analog Output 3
174	Gas1 Over Ranging	0 = Over Ranging Disabled 1 = Over Ranging Enabled (Gas1)
175	Gas2 Over Ranging	0 = Over Ranging Disabled 1 = Over Ranging Enabled (Gas2)
176	Gas3 Over Ranging	0 = Over Ranging Disabled 1 = Over Ranging Enabled (Gas3)
177	Heater Set Point	Cell Heater Set Point
178	PMT HV Ctrl POT	PMT High Voltage Controller POT
179	PMT Test LED POT	PMT Test LED intensity controller POT
180	Last Power Failure Time	Time Stamp of the Last power fail (4 byte time stamp) Bit 31:26 ---- Year (0 – 99) Bit 25:22 ---- Month (1 – 12) Bit 21:17 ---- Date (1 – 31) Bit 16:12 ---- Hour (00 – 23) Bit 11:06 ---- Min (00 – 59) Bit 05:00 ---- Sec (00 – 59)

#	Description	Notes
181	Instantaneous Manifold Pressure	Instantaneous Manifold Pressure in S40 analysers (no filter)
182	Calibration Pressure 2	
183	Gas 4 (NH_3) Concentration	
184	Gas 5 (N_X)Concentration	
185	Gas 4 (NH_3) Average Concentration	
186	NH_3 Conv. Efficiency	
187	Cell/Lamp M/S Ratio	
188	Mirror T. M/S Ratio	
189	Flow Temp M/S Ratio	
190	Cooler T. M/S Ratio	
191	NO Conv T. M/S Ratio	
192	CO Conv T M/S Ratio	
193	F/Scale Curr Gas 1	
194	F/Scale Curr Gas 2	
195	F/Scale Curr Gas 3	
196	Z Adj Curr Gas 1	
197	Z Adj Curr Gas 2	
198	Z Adj Curr Gas 3	
199	Ext Analog Input 1	
200	Ext Analog Input	
201	Ext Analog Input	
202	Converter Set Point	

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Appendix B. EC9800 Protocol

The following commands are supported.

DCONC

Function	Sends the current instantaneous concentration data to the serial port.
Format	DCONC,{<DEVICE I.D.>}{TERMINATOR}
Device response	{GAS}<SPACE>{STATUS WORD}<CR><LF>

All numbers are in floating point format. The STATUS WORD indicates the instrument status in hex using the following format:

Bit 15 = SYSFAIL (MSB)
Bit 14 = FLOWFAIL
Bit 13 = LAMPFAIL
Bit 12 = CHOPFAIL
Bit 11 = CVFAIL
Bit 10 = COOLERFAIL
Bit 9 = HEATERFAIL
Bit 8 = REFFAIL
Bit 7 = PS-FAIL
Bit 6 = HV-FAIL
Bit 5 = OUT OF SERVICE
Bit 4 = instrument is in zero mode
Bit 3 = instrument is in span mode
Bit 2 = unused
Bit 1 = SET→PPM selected, CLEAR→MG/M3
Bit 0 = reserved (LSB).

DSPAN

Function	Commands the unit under test to enter the span mode and stay there.
Format	DSPAN,{<DEVICE I.D.>}{TERMINATOR}
Device response	<ACK> if the unit under test is able to perform the command, <NAK> if not.

DZERO

Function	Commands the unit under test to enter the zero mode and stay there.
Format	DZERO,{<DEVICE I.D.>}{TERMINATOR}
Device response	<ACK> if the unit under test is able to perform the command, <NAK> if not.

ABORT

Function	Commands the addressed device to abort the current mode and return to the measure mode.
Format	ABORT,{<DEVICE I.D.>}{TERMINATOR}
Device response	<ACK> if the unit under test is able to perform the command, <NAK> if not.

RESET

Function	Reboots the instrument (software reset).
Format	RESET, {<DEVICE I.D.>}{TERMINATOR}
Device response	<ACK>

Appendix C. Bavarian Protocol

All Bavarian Network commands follow the command format as specified in this section.

Bavarian Network Command Format

<STX><text><ETX>< bcc1><bcc2>

Where:

<STX> = ASCII Start Of Transmission = 0x02 hex

<text> = ASCII text maximum length of 120 characters

<ETX> = ASCII end of transmission = 0x03 hex

<bcc1> = ASCII representation of block check value MSB

<bcc2> = ASCII representation of block check value LSB.

The block check algorithm begins with 0 and exclusive-OR's each ASCII character from <STX> to <ETX> inclusive. This block check value is then converted to ASCII format and sent after the <ETX> character.

Examples

The following is an example of a valid Bavarian data request for an instrument that has an ID of 97:

<STX>DA097<EXT>3A

The block check calculation is best shown by the following example:

Character	Hex Value	Binary	Block Check
<STX>	02	0000 0010	0000 0010
D	44	0100 0100	0100 0110
A	41	0100 0001	0000 0111
0	30	0011 0000	0011 0111
9	39	0011 1001	0000 1110
7	37	0011 0111	0011 1001
<ETX>	03	0000 0011	0011 1010

The binary value 0011 1010 corresponds to the hex value 3A. This value in ASCII forms the last two characters of the data request message. Please note that the I.D. of 97 is sent as the sequence 097. All I.D. strings must have 3 digits and the user should always pad with ASCII zero characters.

This is an example of a valid command to put the unit in the manual span mode if the instrument has an ID of 843:

<STX>ST843 K<ETX>52

The block check operation is best shown with the following table:

Character	Hex Value	Binary	Block Check
<STX>	02	0000 0010	0000 0010
S	53	0101 0011	0101 0001
T	54	0101 0100	0000 0101
8	38	0011 1000	0011 1101
4	34	0011 0100	0000 1001
3	33	0011 0011	0011 1010
‘ ‘	20	0010 0000	0001 1010
K	4B	0100 1011	0101 0001
<ETX>	03	0000 0011	0101 0010

The binary block check value is 0101 0010 which is the hex value 52 as shown at the end of the command string.

Supported Commands

The command set supported by the Bavarian protocol is:

Table 9 - Bavarian Protocol Commands

Command	Effect
DA<id>	Returns gas concentration
DA	Returns gas concentration w/o id
ST<id> M	Enter Measure mode
ST<id> N	Enter Zero mode
ST<id> K	Enter Span mode
ST<id> S	Force a background check

DA

Return the current instantaneous concentration.

Format

<STX>{DA}{<kkk>}<ETX>< bcc1><bcc2>

or

<STX>{DA}<ETX>< bcc1><bcc2>

Where:

kkk = Device’s multidrop ID

bcc1 = first byte of the block check calculation

bcc2 = second byte of the block check calculation

Device response (S10, S30, and S50 family)

<STX>{MD}{01}<SP><kkk><SP><+nnnn+ee><SP><ss><SP><ff><{000}><SP>{00000000}

<SP><ETC>< bcc1><bcc2>

Device response (S40 family)

<STX>{MD}{02}<SP><kkk><SP><+nnnn+ee><SP><ss><SP><ff><SP>{00000000}

<SP><mmm><SP><+pppp+ee><SP><ss><SP><ff><SP>{00000000}

<SP><ETC><bcc1><bcc2>

Where:

<SP> = space (0x20 hex)

kkk = Device’s multidrop ID. If the DA command is issued without an ID, then the response omits this field. Exception: the S40 family always includes both ID fields, even when a DA command without an ID is issued.

+nnnn+ee = Main instantaneous gas concentration (for S40 family, this is NO)

ss = status byte with the following bit map:

Status Bit	Meaning if set to 1
0	Instrument off (this value is always set to 0)
1	Out of service
2	Zero mode
3	Span mode
4	-
5	-
6	Units: 1 = Volumetric, 0 = Gravimetric
7	Background mode (S30 and S50 family only)

ff = failure byte for both channels with the following bit map (positive logic):

Failure Bit	Meaning if set to 1
0	Flow sensor failure
1	Instrument failure
2	-
3	Lamp failure (S40 family only)
4	-
5	Cell heater failure (S30, S40 and S50 family only)
6	-
7	-

mmm = NO instrument ID

+pppp+ee = NOx gas concentration (unless the NO_2 option was selected in the Serial **Communications Menu**, in which case it is NO_2)

bcc1 = first byte of the block check calculation

bcc2 = second byte of the block check calculation

ST

Set the instrument mode.

Format

<STX>{ST}{< kkk>}<SP>{command}<ETC><bcc1><bcc2>

Where:

kkk = Device's multidrop ID

command = M, N or K for Measure, Zero, or Span mode

bcc1 = first byte of the block check calculation

bcc2 = second byte of the block check calculation

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Appendix D. ModBus Protocol

The Serinus supports a limited Modbus implementation.

The only function codes supported are 3 (Read holding register) and 16 (Write multiple registers).

Read Holding Register

You must specify a slave address for Serial requests (but not for TCP requests). This value is the Serinus's Multidrop ID.

Read requests specify which Advanced Protocol IEEE value they want to read as the starting reference (indexed from 0). Refer the appendix on the Advanced Protocol to see what values are available and what index to specify for them.

You may read from 2 to 124 registers. Note that you must read an even number of registers, because the return data is always 4 bytes (a float).

The Serinus expects 8 data bits, 1 stop bit, and no parity. The baud rate is specified by the Serial **Communications menu**.

The value will be returned as a big-endian 32-bit IEEE floating point value.

Write Multiple Registers

You must specify a slave address for Serial requests (but not for TCP requests). This value is the Serinus's Multidrop ID.

The start reference is the same as for reading.

Only 2 registers may be written at a time; that is, a single IEEE value. Currently only the supported value is 85, to put the instrument into span (3), zero (2), cycle (1), or measure (0) mode.

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Appendix E. Beer-Lambert Law

The Beer-Lambert equation, shown below, is used to calculate the concentration of ozone from the ratio of the two light intensities measured:

$$I/I0 = \exp(-acd)$$

Equation 7 Beer-Lambert Law

where

- I is the light intensity measured with ozone in the gas sample
- I0 is the light intensity measured with no ozone in the gas sample
- a is the ozone absorption coefficient at 253.7 nm (1.44 x 10-5 m2/mg)
- c is the mass concentration of ozone in mg/m3
- d is the optical path length in m

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